

# ELECTRONICS TECHNICIAN 2

VOL. 1

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# **ELECTRONICS TECHNICIAN 2**

**VOL. 1**

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V. 1

## PREFACE

*Electronics Technician 2, volume 1*, is one of a two-volume series written as an aid to enlisted men who are preparing for advancement to ET 2. This book is one of a series of Navy Training Courses designed to give enlisted men the background material necessary to perform the duties of their rate.

This text in combination with *Electronics Technician 2, volume 2*, contains information about test equipment, transmitters, receivers, radar, sonar, loran, and radiac needed by the Electronics Technician in performing his duties within the rate of ET 2. This text may also be issued as a reference text to strikers for the rate of ET 3.

In preparation for the emergency rates ETN 2, ETR 2, and ETS 2, the applicant should select from both volumes those topics pertaining to his particular rate, as set forth in appendix II of this volume. Volume II is of primary interest to the prospective ETR 2.

As one of the NAVY TRAINING COURSES, this book was prepared by the U. S. Navy Training Publications Center under the supervision of the Bureau of Naval Personnel.

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## CREDITS

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<i>Source</i>	<i>Figure</i>
Robert Stollberg's "Electricity" Monograph No. 3, Copyright 1941, by permission of Bureau of Publications Teachers' College, Columbus University, publishers.	2-1.—D'Arsonval movement.
Reprinted from The Radio Amateur's Handbook.	3-22.—Pictorial diagram of an absorption wave-meter.



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# CHAPTER

# 1

## RESPONSIBILITIES OF THE ET2

### SHIPBOARD ORGANIZATION

All naval vessels are operated under standard administrative and battle organizations to facilitate quick expansion from peacetime to war status without major change. This organization divides the ship's personnel into the (1) Operations, (2) Navigation, (3) Gunnery, (4) Engineering, (5) Supply, and (6) Medical Departments. Aircraft carriers and seaplane tenders have in addition an Air Department, and repair ships and tenders have a Repair Department.

#### Engineering Department

The Engineering Department in large ships normally consists of six divisions, as illustrated by the organization chart in figure 1-1. The Electronics Division is under the Electronics Repair Officer. The Electronics Division is the T division. The Assistants to the Engineer Officer are charged primarily with the operation, maintenance, and repair of the machinery and equipment allotted to their divisions.

## Duties of the Electronics Technician

The duties of an Electronics Technician, Second Class, comprise both military and specialist duties. The military duties are the same as those of other petty officers regardless of their specialty ratings. These military duties are explained in the *General Training Courses for Petty Officers*, NavPers 10601 and NavPers 10603, and in certain articles of *Navy Regulations*.

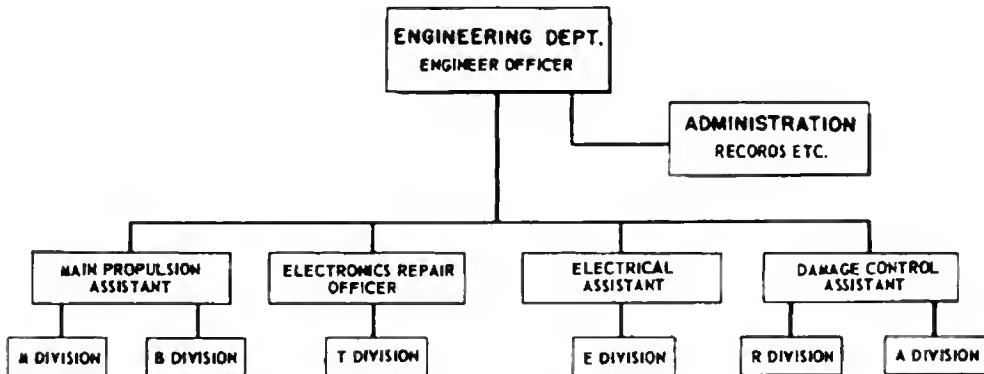


Figure 1-1.—Organization chart of the Engineering Department.

The general specialty duties of Electronics Technicians are to maintain and repair all electronic equipment. This equipment includes radio; radar; sonar; electronic countermeasures; and other types of communications, detection, and ranging equipment employing electronic circuits. These do not include aircraft electronic equipment and ordnance electronic equipment. The Electronics Technician must also be able to use special testing equipment, such as multimeters, vacuum-tube voltmeters, tube testers, signal generators, frequency meters, and cathode-ray oscilloscopes. The technician must be able to disassemble equipment and replace defective parts and also to calibrate, tune, and adjust equipment.

Specifically the Electronics Technician, Second Class, besides being able to carry out the duties of a Third Class, must be able to perform the duties outlined in the *Manual of Qualifications for Advancement in Rating* (NavPers 18068).

# **SHIPBOARD INTEGRATED ELECTRONICS MAINTENANCE PARTS SYSTEM**

## **Introduction**

The inadequacy of boxed sets of maintenance parts to service electronic equipments on board ships led to the Shipboard Integrated Electronics Maintenance Parts System. In many instances, spare parts sets could not be stowed aboard ship because of the large number of boxes and the limitations of shipboard space. As ships are converted to the new system, parts formerly furnished in boxes on a "per equipment" basis are furnished in accordance with an allowance on a "per ship" basis, and like items are group-stocked in standard Navy stock number (SNSN) sequence.

## **Maintenance Parts Allowances**

In establishing parts allowances to provide adequate maintenance parts for electronic equipments installed in each vessel of the fleet, the new system takes advantage of the fact that in every ship there are different types of equipments, each containing some of the same type of parts. Those parts that find common application in more than one type of equipment are known as PARTS COMMON, while those that are peculiar to just one type of equipment are known as PARTS PECULIAR.

To determine the number of applications for each part aboard a particular ship, the Bureau of Ships refers to the latest Ship Electronic Installation Record (Nav-Ships 4110) submitted by that ship in order to ascertain the number and kinds of equipments that must be supported by the allowance. The total parts applications in the installation is then obtained by combining the number of parts applications for each equipment.

Parts allowances are made up of two sections—Electron Tube Allowance, and Maintenance Parts Allowance.

Each item on the allowance is identified by a standard Navy stock number (SNSN) and like items carried on board are group-stocked under the appropriate number in SNSN sequence.

### **Weight and Space Reduction**

By eliminating the duplications of parts furnished under the old system of spare parts boxes, the present system reduces the total quantity it is necessary to carry on board. Thus the weight and space formerly required for carrying parts are also reduced. Figure 1-2 shows the



**Figure 1-2.—Drawers and bins for stowing spare parts.**



bins and drawers in which parts are stowed under the new system. To increase the ease with which parts can be located, the name and SNSN of the items stowed therein are indicated on each drawer compartment and bin.

### **Inventory Control**

Under the boxed spare parts system the annual inventory of parts was both difficult and time consuming. Under the bin stowage system, it is comparatively simple. By keeping the Spare Parts Stock Record cards (figure 1-3) up to date at all times, an accurate running account of stock on hand may be maintained. Thus when inventory is required, it is necessary only to transfer the information from the stock record cards.

## **FUNDS**

### **Naval Stock Fund**

Practically all general supplies of the Navy are procured through the Naval Stock Fund (NSF). This fund is used to buy supplies in advance of their actual need. The supplies are held in the Naval Stock Account (NSA) until issued. At that time the Naval Stock Fund is paid back from the appropriation covering the purpose for which the material is used. For instance, suppose a ship orders some screw drivers. They are issued from the Naval Stock Account and charged to the final appropriation, Ships and Facilities, Navy, and the ship's allotment. This money is credited to the Naval Stock Fund so that more screw drivers can be bought.

The Naval Stock Account is a stores account, in which material procured by money from the Naval Stock Fund is held, pending issue and charge to final appropriation. The Naval Stock Account is material, and the Naval Stock Fund is money. The value of the material in the account plus the amount of money in the fund is equal to the original Naval Stock Fund. The NSF is a revolving fund, and when paid for, goods in NSA become money again.

SPARE PARTS STOCK RECORD NAV. S. AND A. FORM 488						
TABULATING MACHINE USERS PLEASE NOTE:						
Print Desc. and Stock No. in Block Indicated.						
Print Unit of Issue as Required by Design of Tab Cara						
Print Mat on Tab Machine and Duplicate.						
DATE	VOUCHER	REC'D. FROM OR ISSUED TO	REC'D.	ISSUED	BALANCE	
4/1/52	BALANCE BROUGHT FORWARD					16
4/28		ELECTRONICS (ENG)	—	1	15	
5/7	919760/0	NSC NORVA	10	—	25	
5/11		ELECTRONICS (ENG)	—	1	24	
6/1		"	—	2	22	
LOC. NO.	BOX NO.	PRICE	UNIT	LOW LIMIT	ALLOWED	
2-75-4-Q		.08	EA.	15	25	
DESC. RESISTOR, FIXED COMP., AXIAL WIRE LEAD, 20HM, 5%,						
STOCK NO. N16. R-48967-606 0.5 W						

Figure 1-3.—Spare Parts Stock Record card.

### Appropriation Purchases Account

The Appropriation Purchases Account (APA) is used to account for material of a specialized nature. Items which fall under this account include maintenance repair parts. Such material is purchased with funds provided directly from an appropriation and is placed in storage ashore in the APA, pending issue for use. The cost of material acquired under APA is not charged against a ship's allotment. The ship's allotment is broken down into departmental budgets. The amount of money from this allotment available to each department is determined by the commanding officer.

## REQUESTS FOR MATERIAL

### Authority for Requests

Issues for shipboard use are made by the supply department when a request from a ship's department is received.

The head of each department aboard has the authority to request stores for use in his department. Each request for material is signed by the department head or an officer designated by the department head.

### Preparation of Requests

Request for general stores material (GSM) are prepared on a Stub Requisition (NavSandA form 307). One of these forms is shown in figure 1-4. Only one class of

STUB REQUISITION (After NAVSAND A FORM 307 REV 10-51)							
U.S.S.		DEPARTMENT STUB NO.		DATE		STUB REQ'D NO.	
MISSOURI BB63				24 Nov 52			
ONE STUB	CLASS	EXPENDITURE AC NO.	ALLOTMENT NO.	APPROPRIATION	BY AUTHORITY OF HEAD OF DEPARTMENT (Signature)		
					F. W. Smith CDR USN		
STOCK OR PART NO.	DESCRIPTION OF ARTICLE			QUANTITY REQUIRED	UNIT OF ISSUE	UNIT PRICE	EXTENSION
	HACKSAW FRAME			1	EA.		
	PISTOL GRIP, TYPE B						
RECEIVED BY				AMOUNT OBLIGATED		TOTAL	
ISSUED BY				POSTED TO	STUB NO.	STUB NO.	STUB NO.

Figure 1-4.—Information entered on stub requisition by the technician.

material is entered on a particular stub. In some cases the Electronics Technician has the standard Navy stock numbers and can also fill in the numbers on the stub. When the stub requisition is presented at the GSM issue room, each request is screened to ensure that it has been filled out correctly.

### Stub Record Book

When it has been determined that an issue is to be made and a stub requisition is properly prepared for the

issue, the requisition is assigned the next number in the series maintained separately for each department. A stub record is kept for each department, and original entries are made in it at the time stubs are cleared in the supply office for presentation to the GSM storeroom. Notice in figure 1-5 the additional entries made on the stub by the supply office storekeeper.

STUB REQUISITION (ARMS) NAV II AND A FORM 800 (REV. 10-50)

U.S.S. <b>MISSOURI BB63</b>				DEPARTMENT STUB NO.	DATE <b>24 Nov. 52</b>	STUB REG'T NO. <b>1022 OPER</b>
COAL. SYM- BOL <b>G</b>	CLASS <b>41</b>	EXPENDITURE A/C NO. <b>13111</b>	ALLOTMENT NO.	APPROPRIATION	BY AUTHORITY OF HEAD OF DEPARTMENT <b>F. W. Smith CDR USN</b>	
STOCK OR PART NO.	DESCRIPTION OF ARTICLE			QUANTITY REQUIRED	UNIT OF ISSUE	UNIT PRICE
<b>G-41-F-3394</b>	<b>HACKSAW FRAME</b>			<b>1</b>	<b>EA.</b>	ASSIGN NEXT NUMBER IN OPERATIONS DEPARTMENT SERIES. A SEPARATE SERIES IS MAINTAINED FOR EACH DEPARTMENT
	<b>PISTOL GRIP TYPE B</b>					
RECEIVED BY				AMOUNT OBLIGATED		TOTAL
ISSUED BY				POSTED TO	BOOK TALLY	BOOK RECORD
				PROPERTY CONTROL LEDGER	DEPARTMENTAL BUDGET RECORD	ALLOTMENT RECORD

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CHECKED AGAINST DEPARTMENTAL BUDGET RECORD TO MAKE SURE ALLOTMENT IS NOT OVEREXPENDED

Figure 1-5.—Additional information entered on stub requisition in supply office.

### Items That Cannot Be Issued

When a stub requisition contains an item or items that are ordinarily carried but which are not in stock at the time, those items normally are canceled, and the department is requested to submit another stub after stock replenishment.

When a stub contains an item or items which cannot be supplied from stock and which are not ordinarily carried in stock, such items are ordered by the supply department. The stub is held, unnumbered, in the supply office until the material is received.

STUB NOT HONORED  
UNLESS SIGNED BY  
DEPT HEAD OR REP.  
REPRESENTATIVE AND  
PROPERLY NUMBERED  
BY SUPPLY OFFICE

STUB REQUISITION (AFPM) NAVY S. AND S. FORM 107 (REV. 10-50)					DEPARTMENT STUB NO.		DATE		STUB NO.	
U.S.S. <b>MISSOURI BB63</b>							<b>24 Nov. 52</b>		<b>1022 OPER</b>	
COG. STUB REL.	CLASS	EXPENDITURE AC NO.	ALLOTMENT NO.	APPROPRIATION	BY AUTHORITY OF HEAD OF DEPARTMENT (Signature)					
<b>G</b>	<b>41</b>	<b>13111</b>			<b>F.W. Smith CDR USN</b>					
STOCK OR PART NO.	DESCRIPTION OF ARTICLE			QUANTITY REQUIRED	UNIT OF ISSUE	UNIT PRICE	EXTENSION			
<b>G41-F-3394</b>	<b>HACKSAW FRAME</b>			<b>①</b>	<b>EA</b>					
	<b>PISTOL GRIP, TYPE B</b>									
RECEIVED BY <b>A.W. Reising ETI</b>					AMOUNT OBLIGATED					
ISSUED BY <b>M.M. Nash SKI</b>					POSTED TO <b>MTA 7</b>					

STUB SIGNED BY  
PERSON RECEIVING  
MATERIAL

ISSUING STOREKEEPER  
SIGNS STUB

ISSUES POSTED TO STOCK  
TALLY CARDS SAME DAY  
THAT ISSUE IS MADE. AT  
CLOSE OF DAY STUBS ARE  
GROUPED ACCORDING TO  
STOCK CLASSES AND STORES  
ACCOUNTS AND TRANSMITTED  
TO THE SUPPLY OFFICE.

1325	G 41 F 3394
Card No.	Stub No.
Article <b>Frame, Hack Saw</b>	
<b>Pistol Grip, Type B</b>	
<b>POSTED</b>	
LOCATION <b>Row 5 Shelf 2</b>	
QTY	UNIT PRICE
<b>50</b>	<b>.60</b>
DATE REC'D ISSUED BALANCE	
<b>7-10-50</b>	<b>50</b>
<b>11-24</b>	<b>1 49</b>

Figure 1-6.—Information entered on stub requisition and stock tally card by issue room storekeeper.

If a stub is submitted containing both items carried in stock and items that have to be ordered, the latter items are canceled. An additional stub listing these items is prepared by the department requesting the material.

### Posting To Stock Tally Cards

If stock tally cards are maintained in storerooms, issues are posted on them the same day that the issue is made. Posting to a stock tally card is shown in figure 1-6.

### Requisitioning GSM Material

The Navy uses a vast number of different items. For example, there are more than 75,000 items listed in the General Stores Section of the *Catalog of Navy Material*. If it is desired to order a certain item from the General Stores Section it is important to get the correct stock

number or parts number and nomenclature on the stub requisition in order to get the item desired. This information is obtained from the General Stores Section of the *Catalog of Navy Material*, which lists and identifies all items of general supplies carried in stock for issue to ships and stations.

The catalog is grouped in 99 classes according to the general physical characteristics or types of material. For example, hand tools are listed under class 41 and general hardware under class 42. Material within one class is grouped on a logical basis with like items placed together. The catalog also gives a short description of a particular item, specifications, illustrations, measurement equivalents, usage data, sources of supply, requisitioning procedure, stowage notes, indexing, standard prices, and unit of issue. Aboard most ships the catalog is used by a storekeeper. However, a knowledge of the catalog is helpful to a technician.

Suppose a technician is ordering a hacksaw frame. The first step is to determine what class of material contains hacksaw frames. They come under class 41. The alphabetical index at the beginning of this class lists hacksaw frames as items 1677 and 1681. The item numbers are arranged numerically and are easy to find. The page listing hacksaw frames is shown in figure 1-7.

Note that there are two types of hacksaw frames listed. Item 1677 has a stock number preceded by a dot. This indicates that this item is obsolete and once stocks have been exhausted they will not be replenished. Should item 1681 be the desired item, the stock number and description is entered on the stub requisition. The stock number is G41-F-3394. On the stub is a square for the cognizance symbol and one for the class. This information can be obtained directly from the stock number. In the example the G indicates that this item is under the cognizance of the General Stores Supply Office and the 41 indicates the



## Cutting Tools

## SAWS, SAW BLADES, and ACCESSORIES (Cont'd)

Unit of Issue: Each (EA)

## Coping Saw

Milers Fails Co. No. 43, or equal.

Spring steel frame, hardwood handle. Holds pin- or loop-type blade. Blade tension is controlled by turning handle. Complete with 6½"-long blade.



Item No.	Stock No.	Throat Depth in.	For Blade Size in.
1667	G41-B-122	4½	6 or 6½

## Nest of Saws



Spec. MIL-S-16000, Type VI

Consists of 1 open grip hardwood handle, and 3 interchangeable straight, tapered blades, slotted to receive tightening bolt in handle.

Item No.	Stock No.	Blades		
		Type	Length, in.	Points per in.
1672	G41-B-325	Keyhole	10	10
		Compass	14	8-10
		Nail cutting	16-18	15

## Hacksaw Frames

Spec. Fed. CCC-F-671

Adjustable steel frame accommodates hacksaw blades as shown in the table. Blades not included.



Item 1681

Item No.	Stock No.	Blade Length in.
<b>STRAIGHT HANDLE, Type A</b>		
1677	G41-F-3360	8, 10, 12
<b>PISTOL GRIP, Type B</b>		
1681	G41-F-3364	8, 10, 12

Obsolescent Item—See Special Notes, page 2.

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## Saw Blades

## HACKSAW



Spec. MIL-B-1367, unless otherwise specified

Width of blade ¼". Packed: Item Nos. 1686-1705, 100 per box; Item Nos. 1709-1714, 100 per box, 10 boxes per carton, 2 cartons per case.

Item No.	Stock No.	Nominal Length, in.	Teeth per in.
<b>REGULAR TUNGSTEN, All Hard, Class I, Type A—</b>			
For general service			
1686	G41-B-1162	10	18
1687	G41-B-1163	"	24
1688	G41-B-1166	12	18
1689	G41-B-1167	"	24
<b>REGULAR TUNGSTEN, Flexible, Class I, Type B—</b>			
More resistant to breakage than Type A			
1693	G41-B-1163	10	18
1694	G41-B-1164	"	32
1695	G41-B-1166	12	18
1696	G41-B-1167	"	32
<b>HIGH-SPEED STEEL, All Hard, Class II, Type D—</b>			
For general use			
1700	G41-B-1168	10	18
1701	G41-B-1168	"	24
1702	G41-B-1170	"	32
1703	G41-B-1172	12	18
1704	G41-B-1173-600	"	24
1705	G41-B-1174-17	"	32
<b>HIGH-SPEED STEEL, All Hard, Spec. MIL-B-15818</b>			
Type I, Class 1—For high productive performance			
1709	G41-B-1169-20	10	18
1710	G41-B-1169-20	"	24
1711	G41-B-1170-20	"	32
1712	G41-B-1172-20	12	18
1713	G41-B-1173-602	"	24
1714	G41-B-1174-19	"	32

\*When stocks are exhausted, substitute High-speed Steel Blades, Item Nos. 1700-1705, in identical sizes.

†When stocks are exhausted, substitute High-speed Steel Blades, Item Nos. 1709-1714, in identical sizes.

## KEYHOLE

Spec. MIL-S-16000, Type V, Class 1 (blade only)  
For use with Item No. 1648.



Item No.	Stock No.	Points per in.	Length in.
1719	G41-B-1268	10	10

Figure 1-7.—Page from the Catalog of Navy Material.

class. The first letter of a stock number is the cognizance symbol and the following two or three digits is the class of the material.

After the stub is signed and approved by the department head it is submitted to the issue desk in the supply office for processing before the material is issued. The storekeeper screens the request to see that the: (1) Material is properly identified and not in critical supply, (2) material is in stock and indicates whether it is or is not chargeable to the departmental budget, (3) departmental budget has an unexpended and unobligated balance sufficient to cover the cost of the material, (4) expenditure account number is entered on the stub, (5) next number in sequence in the department's series of requisitions is assigned and entered on the stub.

When the stub is processed by the supply office the technician takes it to the issue room and receives the material.

The storekeeper posts the issue of material to stock tally cards on the same day the issue is made so that there is an up-to-date running inventory of each item issued as well as the balance on hand. The stock tally card shows only the quantity of material and not the dollar value of material.

The completed stub requisitions are sent daily to the supply office. The quantity of material issued on certain stubs is posted to the ship's stock records. The dollar value of the material is deducted from the outstanding balance of the particular departmental budget involved if the material is NSA. No charge is made to the departmental budget for APA material.

### **Requisitioning Repair Parts**

The procedure for ordering repair parts is similar to that for ordering GSM material. If the Standard Navy Stock Number is known it is entered on the stub requisition together with the circuit symbol and the name of the



REQUEST FOR SPARE PARTS							
NAME OF ACTIVITY OR GROUP				REQUEST NO.		DATE	
Missouri BB63				1022		OHER	
DEPARTMENT				DATE			
Operations				24 November 1952			
SPARE PART BOX NO.				ALLOWANCE LIST GROUP NO.			
8 58-1/12							
STOREHOUSE NO.				PAGE NO.			
ITEM NO.	STOCK NO. OR PART NO.	DESCRIPTION	UNIT	QUANTITY	SPARE PART LIST NO.	ALLOWANCE LIST LINE NO.	
1		Voltage divider	EA	1			
		Resistor R320,					
		Fixed, composition, pigtail, 39000 ohms					
		+ 10% 1/2 watt, insulated					
		Navy Type No. 63360					
ABOVE ITEMS TO BE USED ORIGINALLY <b>Model RBB Receiver</b>							
NAME PLATE DATA	SERIAL NO.	TYPE NO.	MODEL NO.	STYLE			
	1220	CRV-46147	RBB				
	NAVY DRAWING NO.	NAVY DRAWING	P. C.	CONTRACT NO.			
				N00-73056			
	MP	R. P. R.					
	MULTI-PAGE	A. C. OR D. C.	UNRES.				
	PHASE	CYCLE	SCHE.	STROKE			
	SIZE	JOB ORDER NO.	CATALOG NO.	SPECIFICATION NO.			
ADDITIONAL NAME PLATE DATA <b>Model RBB Receiver manufactured by Radio Corporation of America</b>							
OTHER IDENTIFYING INFORMATION							
MANUFACTURER				LATEST ACCEPTABLE DELIVERY DATE			
International Resistance Corp.				2 January 1953			
MANUFACTURER'S ADDRESS							
Philadelphia, Penna.							
SOURCE OF SUPPLY							
DATE OUT OF SPA.				UPON RECEIPT NOTIFY			
SUBMITTED BY				APPROVED BY HEAD OF DEPARTMENT			
DATE ORDERED		ORDERED FROM		REQUISITIONING INFORMATION TYPED IN BY SUPPLY OFFICE PERSONNEL		REQUISITION NO.	

Figure 1-8.—Request for Spare Parts (NavSandA form 302).

equipment. If the Standard Navy Stock Number is not known, it is necessary to fill in not only a stub requisition but also a Request for Spare Parts (NavSandA form 302), shown in figure 1-8.

The following information, if available, is entered on the Request for Spare Parts:

1. Full description of electrical and physical characteristics of item.
2. Equipment name.
3. Circuit symbol of item.
4. Manufacturer's reference number.
5. Joint Army-Navy military or Army-Navy aeronautical type number.
6. Contractor's part or drawing number.
7. Navy type number.
8. Army Signal Corps stock numbers.

After the stub requisition is filled at the storeroom each issue is followed by a replacement requisition (usually NavSandA form 43). This is done so that an adequate supply is kept on hand for future issue. The procedure varies because some ships have boxed repair parts and some ships have been converted to the Integrated Electronics Maintenance Parts Stowage System.

A Requisition and Invoice (NavSandA form 43) is shown in figure 1-9. This form is used by the supply department for ordering parts from the supply activity ashore.

The information on the stub requisition and the Request for Spare Parts is used in filling in NavSandA form 43. Only material of the same cognizance symbol and class is entered on a single requisition. If the material does not have stock numbers, only items applicable to a single equipment or accessory are entered on the requisition. Requisitions are submitted to the nearest source of supply of electronic material. They are distributed as follows:

1. Original and six copies to the supply activity.
2. One copy to the requisition file.
3. One copy to the general receiving file or to the maintenance repair parts storekeeper as appropriate.

# REQUISITION AND INVOICE

Rev. 8, and A. Form 43  
Revised July 1952

EB63-

Requisition No. 108-53-2

(IMPORTANT - Vendor shall include only items in one stock class on this form)

Invoice No.

To: Supply Office NSC, Norfolk, Va. (189)		U. S. S. MISSOURI BB63 1063	
The following articles, which are not in excess, are requested.		Date 24 Nov. 1953	Bureau SP18
Deliver to: Supply Officer, USS Missouri BB63 Berth 53, US Navy Shipyard, Norfolk, Va.		Appropriation chargeable 1731601.28 S and FR Allotment 51266	
By 31 Nov. 1953 Priority D		Expenditure account 13111	
Packages to be marked Supply Officer USS Missouri BB63 Req. 108-53-2		Date of shipment	Bill of Lading No.
Remarks		Shipped via	

*R. P. Ayers*

R. P. Ayers, Lt. JG, U. S. N.

Item No.	Standard Stock Catalog No. or Class No.	Description of Article CLASS	Unit of Quantity	Quantity Required	Quantity Furnished	Unit Price	EXTENSION
1		Voltage divider Resistor R320, Fixed, composition, pigtail, 39,000 ohms $\pm 10\%$ 1 watt, insulated Navy Type No. 63360  Nameplate data: REB Serial 1220 Type No. CRV-46147 Contract No. NCo-73056	EA	1			

COMPLETE  
DESCRIPTION  
OF MATERIAL

PREPARED  
BY SUPPLY  
OFFICER FROM  
INFORMATION SUBMITTED  
ON STUB REQUISITION  
S. AND A. FORM 307  
AND REQUEST FOR  
SPARE PARTS  
S. AND A. 302

TOTAL

Checked by	Packed by	Posted and	and the above-mentioned articles
Rechecked	Extended	Verified	
Issued by			

U. S. N.

Figure 1-9.—Requisition and Invoice (NavSandA form 43).

The stub requisition and, if submitted, NavSandA form 302 are filed in the supply office with a copy of the Requisition and Invoice when material is ordered from a supply activity. This ensures that when the material

arrives on board it is sent to the person who ordered it. This procedure is important because the storekeeper is not able to identify most spare parts. With this system the storekeeper identifies each box of material by the requisition number appearing on the box. Then by checking back into the file and obtaining the copy of the requisition together with the stub, the storekeeper can readily identify the department or person ordering the material.

## RECORDS AND REPORTS

### Maintenance History

The *Bureau of Ships Manual* states that each activity engaged in the operation of electronic equipment shall maintain suitable cards for recording the results of inspections of equipments as well as any tests and field changes made. The manual states further that a MAINTENANCE HISTORY, composed of cards filed in loose-leaf binders, supersedes the machinery history and hull repair books formerly required aboard ship. Such cards as the Machinery History Card (NavShips 527), the Electrical History Card (NavShips 527-A), the Electronic Equipment History Card (NavShips 536), and the Hull History Card (NavShips 539) form the basis of the ship's maintenance history. Their purpose is to provide a comprehensive record of the items concerned. They are to be kept up to date and available for inspection at all times and are to be integrated into preventive maintenance programs such as the Current Ships Maintenance Project (CSMP).

In maintaining the maintenance history, an appropriate card is used for each item in the machinery index and for each item in the Ship Electronics Installation Record (NavShips 4110). Entries on the cards include descriptions of equipment failures, repairs effected, alterations and field changes made, tests conducted, and any other information necessary to provide a complete

maintenance history of the items. Routine cleaning and operation are not recorded. The maintenance history cards which the electronics technician must fill in are described as follows.

**ELECTRONIC EQUIPMENT HISTORY CARD (NavShips 536).**—Because this card is the basic maintenance history card for electronic equipment it is discussed in detail. It provides for recording failures and other pertinent information on electronic equipments. A separate card is filled in for each equipment on board. If additional cards are required for an equipment, they are added behind the original card in the binder. All cards for a particular equipment are transferred with the equipment when it is removed from the ship.

The heading of the card is so designed that when the card is properly filled in all the necessary information is readily available for completing the upper part of the U. S. Navy Electronic Failure Report (NavShips 393). The heading of the card should be typed, but entries on the body of the card may be either typed or written in ink or indelible pencil. The following instructions should be

RDZ-1		1204	RECEIVER CNA-46275		1	
Equipment Model Designation		Equip. Ser. No.	Name of Unit and Type No.		Card No.	
Name of Contractor National Company, Inc.		Contract No. RXSF-55624		Date Issued 5 July 1945		Date of 2nd 1204
Location Radio Room C-201-1		Installing activity NRSY				
Type Type	Port No. and Location 2 CFC		Type RA On Board (Date)			
Date	History of Trouble (Ref. U. S. and Table)	Cause or Failure Basic Description of Work Done	Name of Part	Contract Symbol	Part Order No.	Date Received and Manned
4/4/45	NO SIGNALS	OPEN FILAMENT REPLACED V201	TUBE	V201	N10-T-1211	300 4/26/45
4/4/45	P.C. 24					
	RECALIBRATION IN					
	IMPROVE STABILITY					
	OF I.F. AMPLIFIER					

Figure 1-10.—Electronic Equipment History Card (NavShips 536).

followed closely in filling in the form, a sample of which is shown in figure 1-10.

**Equipment Model Designation:** All letters and numbers should be included to indicate the specific model. For instance, AN/ARC-1 should not be entered as AN/ARC or ARC-1.

**Equipment Serial Number:** This number is taken from the equipment nameplate. If an over-all equipment number is not available, the serial number of the major unit is listed for the entire equipment. When it is definitely established that an item does not bear a serial number, an asterisk (\*) is entered in this space.

**Card Number:** The number in this space is "1" for each card in the original file. As additional cards for a specific equipment are filed, they are numbered consecutively.

**Contract Number:** The complete contract number includes all letters and numbers as given on the equipment nameplate.

**Date Installed:** This space refers to the date the equipment was installed. If the installation required several days, the date of completion is the date entered.

**Installing Activity:** This space is for the name of the activity which actually installed the equipment.

**Box Number and Location:** Enter here the locations of all appropriate drawers and bins. In ships not converted to the shipboard maintenance parts system, all maintenance parts are furnished in boxes. The numbers and locations of these boxes are entered here.

**Instruction Book on Board:** Check this space only when the final instruction book is received. If only the preliminary book is on board, this space should not be checked. The appropriate instruction books carry notices of the availability of final instruction books.

**Date:** Enter here the date of a failure, field change, or other work involving maintenance or repair.

**Nature of Trouble:** External evidence of the equipment trouble is entered in this column and should be described in detail. Whenever a field change is made the field change number and title are also shown in this column in addition to the entry required on the Record of Field Changes (NavShips 537).

**Cause of Failure:** This column is most important. Describe how the trouble was traced and what corrective measures were taken. Give detailed information. Note peculiarities and weaknesses. The clearer the information in this column, the more valuable it is to the ship, the Bureau of Ships, and the manufacturer. The information in this column, and that reported on NavShips 383, assists in the production of better and more reliable equipment.

Some activities may wish to record in this column such information as the name and rate of the person actually doing or supervising the work, the man-hours consumed, and the signature of the division officer. Such entries are optional.

**Name of Part:** List here the names of the parts involved in the failure.

**Circuit Symbol:** Record here the symbol designations of the parts that failed, as shown in the instruction book.

**Navy Stock Number:** This space is for the standard Navy stock number, including all prefix and suffix letters, exactly as given in the instruction book.

**Life Hours:** Enter here the estimated life of the part. To obtain this figure use the machinery history cards, readings of elapsed time meters which total the operating time of the part, or any other available data.

**Date NavShips 383 Mailed:** Record the date the Failure Report (NavShips 383) was mailed to BuShips. This column may also be used after completion of a field change to record the date the Field Change Report (NavShips 2369) was mailed.

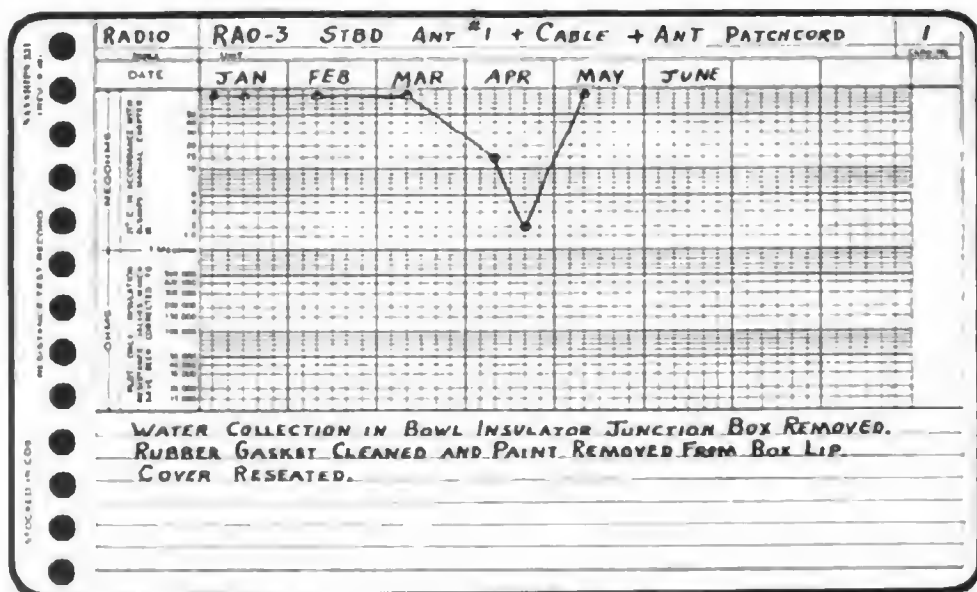


Figure 1-11.—Megger Test Record Card (NavShips 531).

**MEGGER TEST RECORD CARD (NavShips 531).**—This form, shown in figure 1-11, provides for recording the insulation resistance of a unit or circuit. It is inserted in the maintenance history binder adjacent to the applicable equipment history card.

**TUBE PERFORMANCE RECORD (NavShips 538).**—The performance of service-life-guaranteed tubes is recorded on this card. In general such tubes are not used aboard ship. The cards, however, may be used at the ship's discretion for any large or expensive tubes for which it may be desirable to maintain separate records. When used, the cards are inserted in the binder adjacent to the equipment history card for the equipment in which the tube is installed. If the tube is transferred the card is transferred with it. Upon failure of the tube the card may be destroyed after a Failure Report (NavShips 383) has been completed and forwarded to BuShips.

**RECORD OF FIELD CHANGES (NavShips 537).**—Field changes made to any portion of an electronic equipment are recorded on this card, which is filed in the binder



This record is of paramount importance. Without modifications an equipment may be dangerously out of date and subject to numerous serious difficulties. Without a record of field changes it is difficult to determine what modifications, if any, have been made. The information recorded on these cards is essential therefore for routine maintenance, for trouble-shooting, and for ordering maintenance parts which belong to the improved equipment.

[illegible]

The columns headed "Number," "Title of Field Change," and "Authority for Change" are completed in

numerical order for all changes affecting a specific equipment. Field changes affecting given equipments are listed in the appropriate maintenance bulletins—as *Communications Equipment Maintenance Bulletin* (CEMB), *Radar Maintenance Bulletin* (RMB), *Sonar Bulletin*, and *Electronics Maintenance Book* (EMB). Space is provided on the record to indicate these changes by using numbers corresponding to the numbers shown in the bulletins.

**BLANK UTILITY CARD** (NavShips 532).—The purpose of this card is to provide for recording any desired supplementary information. It is inserted in the binder adjacent to the card that it supplements.

### **Current Ship's Maintenance Project**

The purpose of the **CURRENT SHIP'S MAINTENANCE PROJECT** (CSMP) is to provide a current record of maintenance, modifications, and repairs to be accomplished by ship's personnel or during availabilities. The CSMP is composed essentially of the following three cards: Repair Record Card (NavShips 529), which is blue; Alteration Record Card (NavShips 530), which is pink; and Record of Field Changes (NavShips 537), which is white. As a repair is required, or an alteration or field change authorized, the applicable card is filled in and filed in the Material History binder adjacent to the appropriate history card. Being of distinctive colors, the cards readily indicate outstanding work as the binder is examined.

With the exception of the Record of Field Changes, when work is completed, notations to this effect are entered on the material history card and the applicable CSMP cards are removed from the binder and placed in a "completed work" file.

Repair Record Cards and Alteration Record Cards are retained for a period of 2 years after the work noted thereon is completed and entries made in the material history. After the 2-year period, these cards may be destroyed at the discretion of the commanding officer. When

ships are decommissioned or placed out of service during this period, the cards are retained on board.

Electronic Equipment History Cards and Records of Field Changes remain with the equipments referred to on the cards. If the equipment is transferred, these cards are transferred with it.

### **Radar Monthly Performance and Operational Report**

The Bureau of Ships requires monthly reports for certain radar equipments usually because the equipment is comparatively new or of an experimental nature. Those on which monthly reports are required are listed in the *Radar Maintenance Bulletin*. This publication also gives a sample form for this report and detailed instructions for its preparation.

Submitted by Confidential letter, these reports are essential to keeping the Bureau informed on radar performance and operation. Because they provide the bureau with first-hand information on equipments under actual operating conditions, they are of extreme value to the radar program.

### **Electronics Performance and Operational Report (NavShips 3878)**

This report also is important to the Bureau because it furnishes first-hand information on equipments under actual operating conditions. It is not required on all electronic equipments. The Communication Equipment Maintenance Bulletin (NavShips 900,020) lists the equipments for which this report is required and gives detailed information on the correct method for completing NavShips 3878.

Figure 1-13 shows a correctly prepared Electronics Performance and Operational Report. The importance of the space allowed for general remarks is emphasized. In this space should be indicated any information not included elsewhere on the form, such as detailed information on any unusual trouble encountered in operation; ex-

**ELECTRONICS PERFORMANCE AND OPERATIONAL REPORT**  
DD FORM 3070 (11-50)

Submit original **ONLY** to Bureau

01-5070a

FROM: (Ship's Name, Type and Hull No.)		TO: Chief, Bureau of Ships		CLASSIFICATION (If any) (When set, etc.)		DATE	
				<b>RESTRICTED</b>		<b>2 APRIL 1951</b>	
SHIP EQUIPMENT CATEGORY REPORTED ON		PERIOD OF REPORT		FROM		TO	
<input checked="" type="checkbox"/> RADIO <input type="checkbox"/> RADAR <input type="checkbox"/> DME <input type="checkbox"/> OTHER		1 MARCH		1 MARCH		1 APRIL 1951	
MODEL OR TYPE OF EQUIPMENT		<b>RRX RECEIVER</b>					
SERIAL NUMBER	642	638	426	148			
HOURS OF OPERATION DURING PERIOD OF REPORT	300	250	275	30			
HOURS NOT IN OPERATING CONDITION DURING PERIOD OF REPORT	0	8	6	0			
OVERALL PERFORMANCE							
POOR 0 - 40% AVERAGE 50 - 70% GOOD 70 - 100%	90	60	85	90			
APPLICABLE FIELD CHANGES NOT ACCOMPLISHED TO DATE	NONE	4	NONE	NONE			
MAXIMUM RELIABLE RANGE (Radio, sonar, radar, etc.)	18 MILES	12 MILES	16 MILES	19 MILES			
MAXIMUM RELIABLE RANGE (Radar)							
MAXIMUM RELIABLE RANGE (Radar)							
ALTITUDE AT MAXIMUM RELIABLE RANGE (Radar)							
AVERAGE ECHO NO. AND TIME							
AVERAGE VOLTAGE STANDING WAVE RATIO IN RADAR TRANSMISSION LINE							
MAXIMUM (ECHO) SCREEN RANGE	YES	YES	YES	YES	YES	YES	YES
MAXIMUM LISTENING SEARCH RANGE	YES	YES	YES	YES	YES	YES	YES
MAXIMUM SENSITIVITY, NORMAL	FMS	FMS	FMS	FMS	FMS	FMS	FMS

WARNING: This report contains information of a classified nature. It is to be controlled and handled in accordance with the instructions in the instructions to the equipment above. Explanation of actual performance of operational difficulties, etc.

- ① Overheating of transformer, T107, led to insulation breakdown on primary side. Overheating was due to inefficient ventilation in driver compartment. Suggest improvement of ventilation by appropriate increase in size of blower fan and associated motor, B109. This is the third failure of transformer, T107, in the past year.

SIGNATURE

*John Doe, LCDR, USN*

\*NOTE: Report Signal to Noise Ratio in E Units

CLASSIFICATION (If any) (When set, etc.)

REPORT NUMBER

**Figure 1-13.—Electronics Performance and Operational Report (NavShips 3878).**

ceptional maintenance required; and suggestions for improvement in design, tests, and new applications. The forwarding of suggested improvements is not to be construed, however, as authority to modify the equipment in any way. Nor does the forwarding of this report eliminate the requirement for forwarding the Failure Report (Nav-

Ships 383) for each failure of electronic equipment regardless of whether or not an operational report is submitted.

### Electronics Field Change Report (NavShips 2369)

As stated earlier, whenever a field change is completed it is necessary to record this information in the ship's material history and to forward to the Bureau of Ships a report of the completion of the change. Form NavShips 2369, a self-addressed card, has been devised for this purpose and one is included in each field change kit. (See figure 1-14).

For reporting field changes for which no kit is supplied or for which no modification card is available, BuShips suggests the following procedures: Fill in the top part of an Electronics Failure Report (NavShips 383) and write "Navy Field Change (No.) made," under the space allowed for remarks. When properly filled in, the card contains the following information:

Equipment model and serial number;

Unit name and serial number;

Navy field change number;

Date field change made;

Name and rank, rating, or title of person making change.

ELECTRONICS FIELD CHANGE REPORT	
<p><b>IMPORTANT</b></p> <p>1. Specify the overall equipment serial number, and not the unit or component serial number.</p> <p>2. Include ship's number when applicable.</p>	<p>ELECTRONICS FIELD CHANGE NO. <u>4</u></p> <p>EQUIPMENT MODEL OR TYPE <u>RDZ-1</u></p> <p>EQUIPMENT SERIAL NO. <u>1204</u></p> <p>DATE FIELD CHANGE COMPLETED <u>2/12/47</u></p> <p>REPORTED BY <u>GWR</u></p> <p>SHIP AND NUMBER ON STATION <u>LSMR 514</u></p>

Figure 1-14.—Electronics Field Change Report (NavShips 2369).

## Electronic Failure Report (NavShips 383)

Because it is of major importance that the Bureau of Ships be informed promptly of all failures of and deficiencies in electronic equipments, systems, components, parts, and tubes one of the reports most frequently required of the ET is the U. S. Navy Electronic Failure Report.

This report serves several excellent purposes. It (1) provides the Bureau with a comprehensive presentation of the over-all performance of electronic gear, (2) points out the weakest parts of any particular equipment, and (3) forms the basis on which to procure maintenance parts. Because new models (or modifications of old models) are usually in some stage of development, prompt receipt of failure reports enables the Bureau to initiate immediate corrective action to eliminate similar or related deficiencies in subsequent production.

Reported failures are tabulated on IBM cards and regular summaries are made to show at a glance the number and types of failures of any part of any equipment.

The importance of reporting failures and their causes cannot be too highly stressed, particularly if failures occur under actual operating conditions. The reports are to be filled in completely and in conformity with the instructions accompanying the card. Many reports received by the Bureau are valueless because they do not give the essential information required by the form or because the information given is incomplete. When indicating the model or type of equipment include all significant nomenclature, letters, and digits. A separate NavShips 383 (Rev.) is required for each failure. It is important that accuracy of the entry describing the reason(s) for the failure be verified.

A sample of an accurate and complete failure report is shown in figure 1-15. Note that every necessary detail is supplied to give a clear picture of the failure—descrip-

tion, cause, corrective measures, and approximate life. This is the way all failure reports should be made if they are to be of value to the Bureau.

Normally duplicates of failure reports are not required except in the case of certain electron tubes and crystals. Another exception includes shore stations from which the cognizant maintenance yard requires a copy.

Failure reports on electron tubes must be filled in with the same care given any other failure report to ensure accuracy and completeness. Failure report forms are to be submitted for all tubes that fail in storage, handling, installation, or operation, including tubes used in BuAer and BuOrd electronic equipments. As for other reported electronic failures, tube failure reports are used by BuShips to compile the causes and rates of failures, both of which influence the design of tubes and equipment and the number of replacement tubes allowed. Failures due to own gunfire should be so designated.

The form NavShips 383 carries no security classification. Classified military information, including in some

U. S. NAVY ELECTRONIC FAILURE REPORT NAVSHIPS 383 (Rev. 4-54)		NOTICE: 1. Read instructions tabularized in this pad prior to preparing report. 2. Report all failures (Electronic, electrical, and mechanical). 3. Use separate sheet to report each part failure.		REPORT NO. <u>42</u>
EQUIPMENT: (Indicate type, name of ship or station, and location, etc.) <u>USS LSMR 514</u>		SHIP: (Indicate name of ship, yard, and location, etc.) <u>USS LSMR 514</u>		DATE OF FAILURE <u>16 OCTOBER, 1949</u>
SERVICE USER EQUIPMENT (Check one) 1 <input checked="" type="checkbox"/> NAVY 2 <input type="checkbox"/> USCG 3 <input type="checkbox"/> ARMY 4 <input type="checkbox"/> AIR FORCE		TYPE ACTIVITY (Check one) 1 <input checked="" type="checkbox"/> TWP 2 <input type="checkbox"/> SMOKE 3 <input type="checkbox"/> AMBUSH 4 <input type="checkbox"/> AIR-BOAT 5 <input type="checkbox"/> OTHER		REPORTED BY (Signature and title of person) <u>G. W. REISSIG ETI</u>
EQUIPMENT CATEGORY (Check one) 1 <input checked="" type="checkbox"/> RADIO 2 <input type="checkbox"/> RADAR 3 <input type="checkbox"/> SONAR 4 <input type="checkbox"/> TEST 5 <input type="checkbox"/> DISTANCE 6 <input type="checkbox"/> RANGING 7 <input type="checkbox"/> POWER		NAME OF CONTRACTOR <u>NATIONAL COMPANY, INC.</u>		TYPE NO. AND SERIAL NO. OF PART <u>CNA-70294</u>
TUBE IDENTIFICATION <u>RDZ-1</u>		SERIAL NO. <u>1204</u>		DATE OF FAILURE <u>5 JULY, 1945</u>
TUBE PART NO. <u>61C7</u>		TUBE IDENTIFICATION <u>N16-T-56138</u>		DATE OF FAILURE <u>V201</u>
TUBE PART NO. <u>300</u>		TUBE IDENTIFICATION <u>RCA</u>		DATE OF FAILURE <u>V201</u>
CHECK TYPE OF FAILURE		REMARKS: (Include cause of failure and suggested changes (Conclude report by an approved sign))		
001 <input type="checkbox"/> BURNED	130 <input type="checkbox"/> SHORTED	260 <input type="checkbox"/> EXHAUSTED	390 <input type="checkbox"/> SHORTED	520 <input type="checkbox"/> SHORTED
002 <input type="checkbox"/> OPEN	140 <input type="checkbox"/> OPEN	270 <input type="checkbox"/> OPEN	400 <input type="checkbox"/> OPEN	530 <input type="checkbox"/> OPEN
003 <input type="checkbox"/> SHORTED	150 <input type="checkbox"/> SHORTED	280 <input type="checkbox"/> SHORTED	410 <input type="checkbox"/> SHORTED	540 <input type="checkbox"/> SHORTED
004 <input type="checkbox"/> SHORTED	160 <input type="checkbox"/> SHORTED	290 <input type="checkbox"/> SHORTED	420 <input type="checkbox"/> SHORTED	550 <input type="checkbox"/> SHORTED
005 <input type="checkbox"/> SHORTED	170 <input type="checkbox"/> SHORTED	300 <input type="checkbox"/> SHORTED	430 <input type="checkbox"/> SHORTED	560 <input type="checkbox"/> SHORTED
006 <input type="checkbox"/> SHORTED	180 <input type="checkbox"/> SHORTED	310 <input type="checkbox"/> SHORTED	440 <input type="checkbox"/> SHORTED	570 <input type="checkbox"/> SHORTED
007 <input type="checkbox"/> SHORTED	190 <input type="checkbox"/> SHORTED	320 <input type="checkbox"/> SHORTED	450 <input type="checkbox"/> SHORTED	580 <input type="checkbox"/> SHORTED
008 <input type="checkbox"/> SHORTED	200 <input type="checkbox"/> SHORTED	330 <input type="checkbox"/> SHORTED	460 <input type="checkbox"/> SHORTED	590 <input type="checkbox"/> SHORTED
009 <input type="checkbox"/> SHORTED	210 <input type="checkbox"/> SHORTED	340 <input type="checkbox"/> SHORTED	470 <input type="checkbox"/> SHORTED	600 <input type="checkbox"/> SHORTED
010 <input type="checkbox"/> SHORTED	220 <input type="checkbox"/> SHORTED	350 <input type="checkbox"/> SHORTED	480 <input type="checkbox"/> SHORTED	610 <input type="checkbox"/> SHORTED
011 <input type="checkbox"/> SHORTED	230 <input type="checkbox"/> SHORTED	360 <input type="checkbox"/> SHORTED	490 <input type="checkbox"/> SHORTED	620 <input type="checkbox"/> SHORTED
012 <input type="checkbox"/> SHORTED	240 <input type="checkbox"/> SHORTED	370 <input type="checkbox"/> SHORTED	500 <input type="checkbox"/> SHORTED	630 <input type="checkbox"/> SHORTED
013 <input type="checkbox"/> SHORTED	250 <input type="checkbox"/> SHORTED	380 <input type="checkbox"/> SHORTED	510 <input type="checkbox"/> SHORTED	640 <input type="checkbox"/> SHORTED
014 <input type="checkbox"/> SHORTED	260 <input type="checkbox"/> SHORTED	390 <input type="checkbox"/> SHORTED	520 <input type="checkbox"/> SHORTED	650 <input type="checkbox"/> SHORTED
015 <input type="checkbox"/> SHORTED	270 <input type="checkbox"/> SHORTED	400 <input type="checkbox"/> SHORTED	530 <input type="checkbox"/> SHORTED	660 <input type="checkbox"/> SHORTED
016 <input type="checkbox"/> SHORTED	280 <input type="checkbox"/> SHORTED	410 <input type="checkbox"/> SHORTED	540 <input type="checkbox"/> SHORTED	670 <input type="checkbox"/> SHORTED
017 <input type="checkbox"/> SHORTED	290 <input type="checkbox"/> SHORTED	420 <input type="checkbox"/> SHORTED	550 <input type="checkbox"/> SHORTED	680 <input type="checkbox"/> SHORTED
018 <input type="checkbox"/> SHORTED	300 <input type="checkbox"/> SHORTED	430 <input type="checkbox"/> SHORTED	560 <input type="checkbox"/> SHORTED	690 <input type="checkbox"/> SHORTED
019 <input type="checkbox"/> SHORTED	310 <input type="checkbox"/> SHORTED	440 <input type="checkbox"/> SHORTED	570 <input type="checkbox"/> SHORTED	700 <input type="checkbox"/> SHORTED
020 <input type="checkbox"/> SHORTED	320 <input type="checkbox"/> SHORTED	450 <input type="checkbox"/> SHORTED	580 <input type="checkbox"/> SHORTED	710 <input type="checkbox"/> SHORTED
021 <input type="checkbox"/> SHORTED	330 <input type="checkbox"/> SHORTED	460 <input type="checkbox"/> SHORTED	590 <input type="checkbox"/> SHORTED	720 <input type="checkbox"/> SHORTED
022 <input type="checkbox"/> SHORTED	340 <input type="checkbox"/> SHORTED	470 <input type="checkbox"/> SHORTED	600 <input type="checkbox"/> SHORTED	730 <input type="checkbox"/> SHORTED
023 <input type="checkbox"/> SHORTED	350 <input type="checkbox"/> SHORTED	480 <input type="checkbox"/> SHORTED	610 <input type="checkbox"/> SHORTED	740 <input type="checkbox"/> SHORTED
024 <input type="checkbox"/> SHORTED	360 <input type="checkbox"/> SHORTED	490 <input type="checkbox"/> SHORTED	620 <input type="checkbox"/> SHORTED	750 <input type="checkbox"/> SHORTED
025 <input type="checkbox"/> SHORTED	370 <input type="checkbox"/> SHORTED	500 <input type="checkbox"/> SHORTED	630 <input type="checkbox"/> SHORTED	760 <input type="checkbox"/> SHORTED
026 <input type="checkbox"/> SHORTED	380 <input type="checkbox"/> SHORTED	510 <input type="checkbox"/> SHORTED	640 <input type="checkbox"/> SHORTED	770 <input type="checkbox"/> SHORTED
027 <input type="checkbox"/> SHORTED	390 <input type="checkbox"/> SHORTED	520 <input type="checkbox"/> SHORTED	650 <input type="checkbox"/> SHORTED	780 <input type="checkbox"/> SHORTED
028 <input type="checkbox"/> SHORTED	400 <input type="checkbox"/> SHORTED	530 <input type="checkbox"/> SHORTED	660 <input type="checkbox"/> SHORTED	790 <input type="checkbox"/> SHORTED
029 <input type="checkbox"/> SHORTED	410 <input type="checkbox"/> SHORTED	540 <input type="checkbox"/> SHORTED	670 <input type="checkbox"/> SHORTED	800 <input type="checkbox"/> SHORTED
030 <input type="checkbox"/> SHORTED	420 <input type="checkbox"/> SHORTED	550 <input type="checkbox"/> SHORTED	680 <input type="checkbox"/> SHORTED	810 <input type="checkbox"/> SHORTED
031 <input type="checkbox"/> SHORTED	430 <input type="checkbox"/> SHORTED	560 <input type="checkbox"/> SHORTED	690 <input type="checkbox"/> SHORTED	820 <input type="checkbox"/> SHORTED
032 <input type="checkbox"/> SHORTED	440 <input type="checkbox"/> SHORTED	570 <input type="checkbox"/> SHORTED	700 <input type="checkbox"/> SHORTED	830 <input type="checkbox"/> SHORTED
033 <input type="checkbox"/> SHORTED	450 <input type="checkbox"/> SHORTED	580 <input type="checkbox"/> SHORTED	710 <input type="checkbox"/> SHORTED	840 <input type="checkbox"/> SHORTED
034 <input type="checkbox"/> SHORTED	460 <input type="checkbox"/> SHORTED	590 <input type="checkbox"/> SHORTED	720 <input type="checkbox"/> SHORTED	850 <input type="checkbox"/> SHORTED
035 <input type="checkbox"/> SHORTED	470 <input type="checkbox"/> SHORTED	600 <input type="checkbox"/> SHORTED	730 <input type="checkbox"/> SHORTED	860 <input type="checkbox"/> SHORTED
036 <input type="checkbox"/> SHORTED	480 <input type="checkbox"/> SHORTED	610 <input type="checkbox"/> SHORTED	740 <input type="checkbox"/> SHORTED	870 <input type="checkbox"/> SHORTED
037 <input type="checkbox"/> SHORTED	490 <input type="checkbox"/> SHORTED	620 <input type="checkbox"/> SHORTED	750 <input type="checkbox"/> SHORTED	880 <input type="checkbox"/> SHORTED
038 <input type="checkbox"/> SHORTED	500 <input type="checkbox"/> SHORTED	630 <input type="checkbox"/> SHORTED	760 <input type="checkbox"/> SHORTED	890 <input type="checkbox"/> SHORTED
039 <input type="checkbox"/> SHORTED	510 <input type="checkbox"/> SHORTED	640 <input type="checkbox"/> SHORTED	770 <input type="checkbox"/> SHORTED	900 <input type="checkbox"/> SHORTED
040 <input type="checkbox"/> SHORTED	520 <input type="checkbox"/> SHORTED	650 <input type="checkbox"/> SHORTED	780 <input type="checkbox"/> SHORTED	910 <input type="checkbox"/> SHORTED
041 <input type="checkbox"/> SHORTED	530 <input type="checkbox"/> SHORTED	660 <input type="checkbox"/> SHORTED	790 <input type="checkbox"/> SHORTED	920 <input type="checkbox"/> SHORTED
042 <input type="checkbox"/> SHORTED	540 <input type="checkbox"/> SHORTED	670 <input type="checkbox"/> SHORTED	800 <input type="checkbox"/> SHORTED	930 <input type="checkbox"/> SHORTED
043 <input type="checkbox"/> SHORTED	550 <input type="checkbox"/> SHORTED	680 <input type="checkbox"/> SHORTED	810 <input type="checkbox"/> SHORTED	940 <input type="checkbox"/> SHORTED
044 <input type="checkbox"/> SHORTED	560 <input type="checkbox"/> SHORTED	690 <input type="checkbox"/> SHORTED	820 <input type="checkbox"/> SHORTED	950 <input type="checkbox"/> SHORTED
045 <input type="checkbox"/> SHORTED	570 <input type="checkbox"/> SHORTED	700 <input type="checkbox"/> SHORTED	830 <input type="checkbox"/> SHORTED	960 <input type="checkbox"/> SHORTED
046 <input type="checkbox"/> SHORTED	580 <input type="checkbox"/> SHORTED	710 <input type="checkbox"/> SHORTED	840 <input type="checkbox"/> SHORTED	970 <input type="checkbox"/> SHORTED
047 <input type="checkbox"/> SHORTED	590 <input type="checkbox"/> SHORTED	720 <input type="checkbox"/> SHORTED	850 <input type="checkbox"/> SHORTED	980 <input type="checkbox"/> SHORTED
048 <input type="checkbox"/> SHORTED	600 <input type="checkbox"/> SHORTED	730 <input type="checkbox"/> SHORTED	860 <input type="checkbox"/> SHORTED	990 <input type="checkbox"/> SHORTED
049 <input type="checkbox"/> SHORTED	610 <input type="checkbox"/> SHORTED	740 <input type="checkbox"/> SHORTED	870 <input type="checkbox"/> SHORTED	1000 <input type="checkbox"/> SHORTED

Figure 1-15.—Electronic Failure Report (NavShips 383).

cases the operating frequency, is therefore not to be included on this form.

All electron tubes received by a ship, station, or other using activity should be examined immediately upon receipt for obvious breakage, defective packing, or signs of rough handling, and electrical tests should be conducted if feasible. All large or expensive tubes should be checked for filament continuity, shorted elements, and loss of vacuum. When possible, tubes should be checked by operation in an equipment socket under rated operating conditions. Failure reports are then completed and forwarded to the Bureau for all tubes received in defective condition.

## INSTALLATION AND MAINTENANCE PUBLICATIONS

### Electronics Maintenance Book (NavShips 900,000)

As a section of the *Sonar Bulletin*, *Radar Maintenance Bulletin*, or the *Communications Equipment Maintenance Bulletin* is changed, a section is added to the *Electronics Maintenance Book* instead of to the individual bulletin. In time all sections of these books will be completely replaced and all material will be contained in the *Electronics Maintenance Book*.

### Sonar Bulletin (NavShips 900,025A)

A loose-leaf publication, this bulletin groups together in one volume all existing current maintenance information for all types of shipboard and harbor detection sonar equipments. In addition it carries a list of field changes for these equipments, complete instructions for accomplishing all field changes that do not require kits, and a chapter on sonar publications and corrections.

The *Sonar Bulletin* is distributed to all sonar schools, ships with sonar equipment (other than echo sounding), sonar repair ships, sonar installation or repair activities, sonar equipment manufacturers, and any other activities with clearly defined uses for the bulletin. A vessel that



has only echo-sounding equipment on board is not entitled to this bulletin. To reach vessels carrying only this class of sonar equipment, the *Communication Equipment Maintenance Bulletin* gives information on echo sounding.

### **Shipboard Radar Maintenance Bulletin**

This is a loose-leaf publication issued in two editions. It gives information necessary to the efficient maintenance of shipboard radar equipment.

The publication is divided into sections under such headings as general, radar, fire control, and submarine equipment.

The RMB is issued in "C" and "S" editions. The C, or complete, edition is intended for large ships and major activities and contains all sections. The S edition contains only those sections that apply to equipments on the allowances of smaller ships.

### **Communications Equipment Maintenance Bulletin (NavShips 900,020A)**

The *Communications Equipment Maintenance Bulletin* (CEMB) also is a loose-leaf publication. It contains information on the maintenance and repair of all electronic ship-to-ship and ship-to-shore communications equipment used by the Navy. Much of the material promulgated in the CEMB is originated by the engineering staff of the Bureau of Ships through close liaison with personnel of the fleet and naval shipyards. It also includes handy maintenance tricks which have been evolved by technicians in the field, endorsed by the Bureau, and published for the benefit of all maintenance personnel. Electronics Technicians and other maintenance personnel are encouraged to forward to the Bureau any new trick that makes their jobs easier, new procedures that prevent breakdown, or methods by which a stubborn trouble can be overcome.

The section of the *Sonar Bulletin* that is devoted to

echo-sounding equipment is included as a regular section of the CEMB, because vessels having only this class of sonar equipment do not receive the *Sonar Bulletin*.

Distribution of the CEMB is to all ships (except landing craft), all type and force commanders, all advanced bases, and major shore activities.

### **Instruction Books**

These books carry information essential to the proper operation, maintenance, and repair of the equipment to which they apply. Two copies of the instruction book for a particular equipment are normally supplied with the equipment. In addition, the Bureau supplies file copies to activities concerned with the installation and maintenance of the equipment and with the training of electronics personnel. Supplies of books remaining after the initial distribution are stored at the East and West Coast Publications Distribution Centers. These centers then supply small stocks of most books to the various publications and printing offices for issue to individual activities. Where the supply of books is extremely limited, those carried at distribution centers are issued to the publications and printing offices only upon request.

The requirements for instruction books are included as a part of the contract for equipments, the number of books varying with the number of equipments included in the contract. Consequently the quantity of books is always limited, and for this reason distribution is normally limited to recipients of the equipment and to those activities required to service it. A sufficient quantity is obtained, however, to supply the usual file requirements of Navy and Marine Corps electronics schools.

Advance, preliminary, or temporary instruction books may be furnished when a delay in completing final instruction books is anticipated. Such books are to be destroyed upon receipt of final instruction books as indi-

cated by the covering letter forwarded with the final books. If the books to be destroyed are classified, disposal must be in accordance with existing regulations covering the destruction of classified material. Promulgating letters for changes to instruction books indicate the desired disposition of material removed from the basic publications.

Requests for instruction books and other NavShips publications are made to the nearest or most accessible district publications and printing office. In view of the limited number of instruction books printed, and the excessive cost of reprinting when stocks are depleted, requests for instruction books must include a statement of the reason they are required. Normally only those requests for two books per equipment are approved.

In order that an activity's file of publications may be kept up to date, current issues of the various maintenance bulletins issued by BuShips should be examined for information on the availability of handbooks, final instruction books, revisions, supplements, or changes pertaining to the equipments installed at the activity.

With reference to the security of instruction books, the *Bureau of Ships Manual* states that Secret, Confidential, and Restricted instruction books must be handled, transported, and safeguarded as prescribed by *U. S. Navy Regulations* and the *Registered Publications Manual*. Confidential and Restricted instruction books and periodicals should be made available to commissioned, warrant, and enlisted personnel whose duties require knowledge of their contents. Similarly, they should be made available to civilian personnel of the Navy and to Navy contractors whose duties involve the design, manufacture, installation, or maintenance of electronic equipment for the Navy and who have been properly cleared to handle classified matter. The security classification of instruction books for Navy electronic equipment is as specified in

*Security Classification of Electronic Equipment* (JANAP 140 (A)) except when the Chief of Naval Operations determines that a book may be classified lower than the equipment in order to permit a broader distribution.

The security classifications of electronic equipments are under constant review, and classifications are lowered or equipment declassified as soon as national safety, prestige, and the furtherance of public welfare and safety warrant. It is essential, therefore, that the security classification of all instruction books and handbooks be checked against the classification indicated in JANAP 140 (A) including latest changes. Where the security classification given in JANAP 140 (A) for a particular equipment is lower than that indicated on the applicable instruction books, the front cover and title page of the books must be prominently marked with the revised classification.

### **Lists, Catalogs, And Indexes**

**ELECTRONIC EQUIPMENT TYPE ALLOWANCE BOOK** (Nav-Ships 900,115).—Distribution of the complete TAB is limited to certain major commands, and to planning, installation, and supply activities directly concerned with the installation and supply of electronic material. Individual ships receive ONLY those pages that apply to the individual ship type. Such pages are intended for insertion in the ship's on-board copy of the machinery allowance as they constitute the ship's allowance of Group 67 material.

**LIST OF NAVAL ELECTRONIC EQUIPMENT.**—This Confidential publication contains a list of the principal radio, radar, and sonar equipments that have been built or purchased by the Navy and to which model letters have been assigned as of July 1951. It provides brief identifying data for the equipments listed and is distributed to all ships and stations.

CATALOGUE OF ELECTRONIC EQUIPMENT.—This publication furnishes convenient summarized references to the principal Bureau of Ships electronic equipments (except airborne). Because it is beyond the scope of the publication to list all the data on any equipment, it is necessary to consult the applicable instruction book when more complete information is desired. To identify equipments not appearing here, personnel are referred to the *List of Naval Electronic Equipment*.

Although the catalogue as a whole is classified Confidential, each page is classified in accordance with the security applicable to the equipment discussed on that page.

CATALOGUE OF ELECTRONIC TEST EQUIPMENT.—This publication serves the same purpose as the *Catalogue of Electronic Equipment* but is limited to testing devices developed for use in the maintenance of electronic equipments. As a whole it, too, is classified as Confidential, though the individual pages are classified according to the equipment discussed thereon.

RADIAC EQUIPMENT (NavShips 900,141).—Similar to the *Catalogue of Electronic Equipment*, this pamphlet is limited to radioactivity detecting equipment. It was prepared primarily to serve as a handy reference book for use by electronics maintenance personnel and may be requisitioned from the nearest publications and printing office. In the future, the information contained in this pamphlet will be included as a section of NavShips 900,116.

CATALOG OF NAVY MATERIAL, BUREAU OF SHIPS SECTION, PART II.—Published in sections devoted to specific types of materials—such as i-f transformers, a-f transformers, and terminal boards—this catalog is superseding the *Catalog of Navy Type Material* and the *Electronics Material Cross Reference*. The *Catalog of Navy Material*

gives detailed descriptions, applicable reference numbers, and illustrations of the items included.

**CROSS INDEX OF ELECTRON TUBE TYPES (NavShips 900,-119).**—The purpose of this publication is to provide as complete a list as possible of all electron tube types used in Army and Navy equipments and stocked in Service depots, and to furnish a cross reference to any other type numbers or designations these tubes may have. The information contained in the publication may be used as a guide to interchangeability of tubes, but the choice of a substitute tube rests ultimately with those responsible for the proper operation of the equipment in which the tube is used. NavShips 900,119 is furnished automatically to ships and shore activities.

## QUIZ

1. Under standard administrative and battle organizations, what are the names of the different departments of a battleship?
2. Who is in charge of the electronics division?
3. Explain the term "parts peculiar."
4. How does the Bureau of Ships determine the number of applications for each maintenance part aboard a particular ship?
5. How is each item on the parts allowance list identified?
6. How are the maintenance parts stowed under the new parts system?
7. Why is it necessary to requisition spare parts?
8. Why is it necessary to make each entry on a requisition accurately?
9. When a particular equipment is transferred from a ship, what is done with the Electronic Equipment History Card for this equipment?
10. Why is it necessary to make the proper entry on the Record of Field Changes (NavShips 537) after a field change is made to an equipment?
11. Where can a technician find a list of the field changes for a particular equipment?

12. What three cards essentially form the Current Ship's Maintenance Project?
13. If a field change is made and no Electronics Field Change Report Card is available, what procedure should the technician follow?
14. When a technician receives a shipment of electron tubes, what should he do?
15. What book is replacing the CEMB, RMB, and *Sonar Bulletin*?
16. To what activity are requests for instruction books forwarded?
17. Name two sources that describe how classified instruction books are to be handled, safeguarded, and transported.
18. Name the source in which the security classification of instruction books is listed.
19. What type of information is contained in the *Electronics Equipment Type Allowance Book*?





## **TEST EQUIPMENT—MEASUREMENT MULTIMETERS**

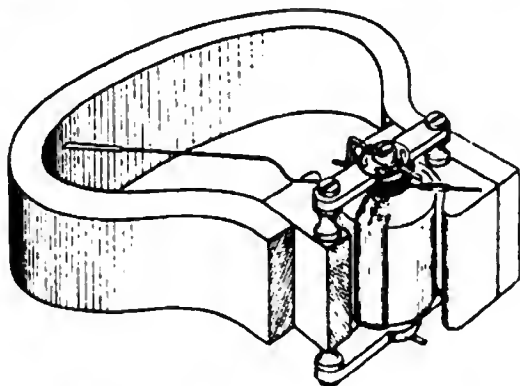
The science of electronics, like all of the physical sciences, depends on accurate quantitative measurement. This involves two important items—numbers and units. Simple arithmetic is used in most cases, and the units are well-defined and understood by the average technician. The standard units of inductance, voltage, and resistance are defined by the National Bureau of Standards.

At the factory various instruments are calibrated by comparing them with established standards. The electronics technician works with voltmeters, ohmmeters, and ammeters. With these instruments the technician measures voltage, resistance, and current. An understanding of the construction and operation, as well as the limitations of the more common types of measuring instruments, is essential in servicing electronic equipment.

### **D'Arsonval Meter**

The D'Arsonval meter movement forms the basic element in the construction of the type of meter used most extensively for making electrical measurements. The essential parts of this movement comprise a movable coil suspended so that it is free to turn in the field of a fixed permanent magnet. A D'Arsonval movement is shown in figure 2-1.

When a direct current flows through the movable coil, a force is created which tends to turn the conductors out of the magnetic field. This turning force is called **DRIVING TORQUE**. The force on the coil is the result of the interaction of the magnetic field created by the coil current



**Figure 2-1.—D'Arsonval movement.**

and the magnetic field of the permanent magnet. Restraining springs are arranged to oppose the driving torque. The resulting displacement of the pointer (attached to the moving coil) is a measure of the torque. Because the permanent magnet field is uniform, the angle of displacement is proportional to the current through the coil.

The coil is wound on an aluminum frame mounted in jeweled bearings. Induced currents are set up in the aluminum frame as it moves through the field of the magnet. These currents tend to damp oscillations of the coil and cause the pointer to come to rest quickly.

The scale of a fundamental D'Arsonval movement may be calibrated in arbitrary units. A movement calibrated in this fashion is called a **GALVANOMETER**. If the instrument is calibrated in microamperes or milliamperes, it is called a **MICROAMMETER** or a **MILLIAMMETER**, respectively. Other instruments such as voltmeters, ammeters, and ohmmeters are modified forms of the basic D'Arsonval movement.

## Voltmeters

A milliammeter can be used to measure voltage by placing a high resistance in series with the moving coil of the meter. The size of the series resistance is determined by the current needed for full-scale deflection of the coil for the particular voltage range. Because the current is directly proportional to the voltage applied, the scale can be calibrated directly in volts for a fixed series resistance.

Suppose that a movement with a full-scale current of one milliampere is to be made into a voltmeter with a full-scale reading of one volt. The total resistance of the meter and the series resistance is found by Ohm's law to be

$$R = \frac{E}{I} = \frac{1}{0.001} = 1000 \text{ ohms.}$$

If the moving coil has a resistance of 50 ohms, the additional series resistance is 950 ohms.

The sensitivity of voltmeters is given in ohms per volt. Sensitivity is equal to the reciprocal of the current (in amperes) required for full-scale deflection. Thus the sensitivity of a 1-milliampere movement is the reciprocal of 0.001 ampere or 1000 ohms per volt. Similarly, the sensitivity of a 50-microampere movement is

$$\frac{1}{50 \times 10^{-6}} = 20,000 \text{ ohms per volt.}$$

The sensitivity of the movement depends on the strength of the permanent magnet field and the number of turns in the moving coil.

**MULTIRANGE VOLTMETERS.**—Multirange voltmeters use one meter movement and a series of tapped resistors. A multirange voltmeter with three ranges is shown in figure 2-2. Voltmeters are usually connected across a circuit. They are seldom connected in series with a circuit. In precision instruments, the series resistors, called **MULTIPLIERS**, are usually wire-wound and have a low temperature coefficient of resistance.

## Ammeters

The fundamental D'Arsonval meter movement can be used to measure only small direct currents because the size of the wire on the movable coil is usually quite small. To measure larger currents, shunts are connected across the coil. The shunt carries that part of the circuit current which is in excess of the safe-carrying capacity of the moving coil itself. In this manner the range of a meter may be built up to any desired current measuring capacity. In order to be able to calculate the required resistance of a shunt, the resistance of the meter movement must be known. This can be obtained from the manufacturer or it can be measured by the voltmeter-ammeter method.

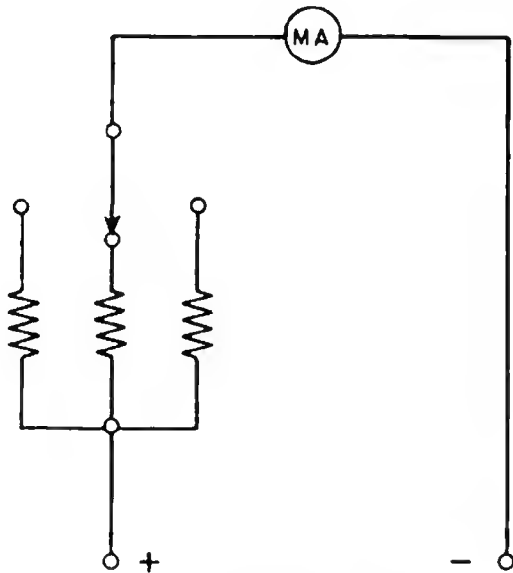


Figure 2-2.—Multirange voltmeter.

Suppose it is desired to convert a 100-microampere D'Arsonval meter having a resistance of 100 ohms to a meter capable of measuring line currents up to 1 ampere. The meter deflects full scale, when the current through the coil is 100 microamperes. Since the resistance of the

coil is 100 ohms, the voltage drop across its terminals for a full-scale deflection is

$$0.0001 \times 100 = 0.01 \text{ volt.}$$

Since the shunt and the meter are in parallel, they both receive the same voltage. Therefore, the drop across the shunt is also 0.01 volt. The shunt resistance is obtained by dividing the voltage drop across the shunt by the current flowing through the shunt. The current through the shunt is equal to the line current minus the meter current.

$$\text{Current through shunt} = 1 - 0.0001 = 0.9999 \text{ ampere}$$

$$\text{Resistance of shunt} = \frac{E}{I} = \frac{0.01}{0.9999} = 0.01 \text{ ohm approximately.}$$

The range of the 100-microampere meter can be increased to 1 ampere by connecting a 0.01-ohm shunt across the meter.

**MULTIRANGE AMMETER SHUNTS.**—Two general switching arrangements for connecting meter shunts are illustrated in figure 2-3. Figure 2-3, A, shows the simpler of the two arrangements. It consists of a one-milliampered-c movement with three shunts of different sizes and a multitap switch. During the time the switch blade is moving from one contact to the next, the shunting effect which protects the meter is removed.

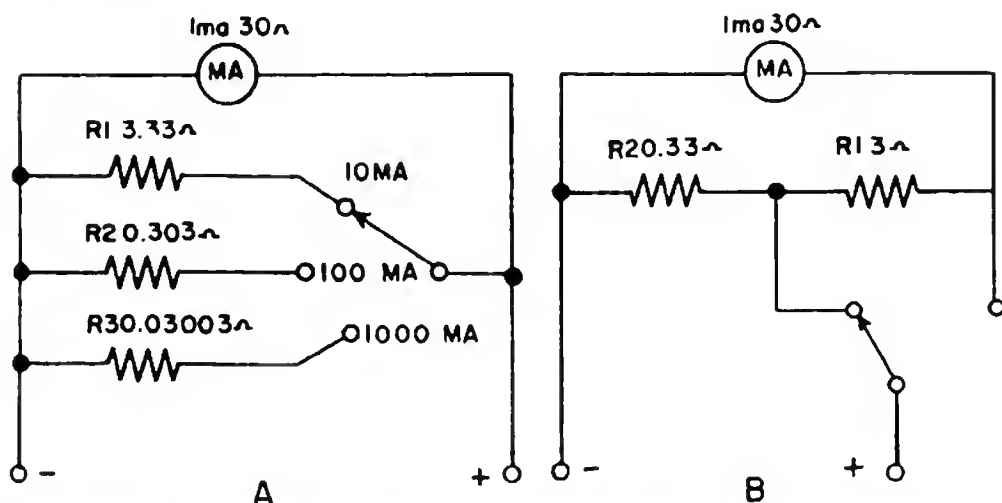


Figure 2-3.—Ammeter shunts. A, Wrong method, B, correct method.

This arrangement is not practical, since the line current would flow momentarily through the movement. A shorting type switch would correct this difficulty. However, another disadvantage still exists and cannot be so easily removed. This disadvantage lies in the fact that the contact resistance of the switch is in series with the shunt resistance but not with the meter resistance. In shunts for measuring larger currents a contact resistance becomes an appreciable part of the total shunt resistance. As this contact resistance is of a variable nature, the ammeter indication is not accurate. Perhaps the only reason for using this switching arrangement lies in the fact that the shunt resistance for each range can be calculated easily with Ohm's law.

The generally accepted method of range switching is that shown in figure 2-3, B. The principle of operation is the same as that of the Ayrton shunt, which has been used for years to extend the range of galvanometer indications. Although only two ranges are shown, as many ranges as needed can be used. The shunt resistance calculations become very lengthy as the number of shunts and range scales is increased. In this type of circuit the range selector switch contact resistance is external to the shunt and meter in each range position. Therefore, it has no effect on the accuracy of the current measurement.

Current-measuring instruments must always be connected in series with a circuit and never in parallel with it. An instrument must have low resistance to minimize power loss. If an instrument were connected directly across a source of appreciable voltage, it would be equivalent to a short circuit across the source. Needless to say, the meter would burn up.

### Ohmmeters

An ohmmeter is a sensitive type d-c milliammeter provided with a source of voltage (usually a few dry cells) and a calibrating resistance. The meter and the battery

are connected in series with the resistance to be measured. The meter scale is calibrated in ohms. A circuit of the basic series-type ohmmeter is shown in figure 2-4.

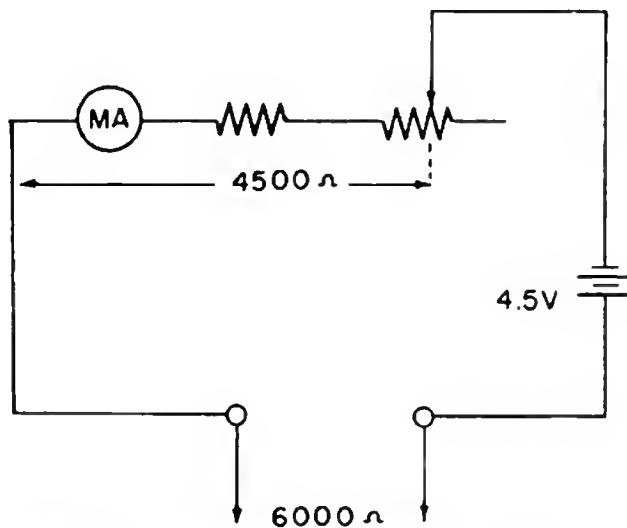


Figure 2-4.—Basic series ohmmeter circuit.

When the test leads are shorted together, the variable resistance is adjusted for full-scale deflection. The point on the meter scale corresponding to full-scale deflection is marked zero resistance. If a 1-milliamperere movement is used with a 4.5-volt battery, the series resistance together with the meter resistance is 4500 ohms. Part of the series resistance is made variable to compensate for changes in the battery voltage.

When the unknown resistance is inserted, the meter reading decreases. For example, a 6000-ohm resistor inserted between the probes decreases the meter current to 0.429 milliamperere. The corresponding point on the scale is marked 6000 ohms.

### Multimeters

A practical instrument for general servicing of electronics equipment is the multimeter. Basically, a multimeter is a microammeter or a milliammeter of the permanent-magnet, movable-coil type with shunts to provide



several current ranges, series resistance multipliers for the corresponding voltmeter scales, and batteries to permit use as an ohmmeter. A multimeter usually has a multipoint switch for quick changes in scales. A meter of this type (the Navy model OCR-1) is shown in figure 2-5.

The D'Arsonval movement is essentially a d-c instrument. Alternating current applied to the moving coil does

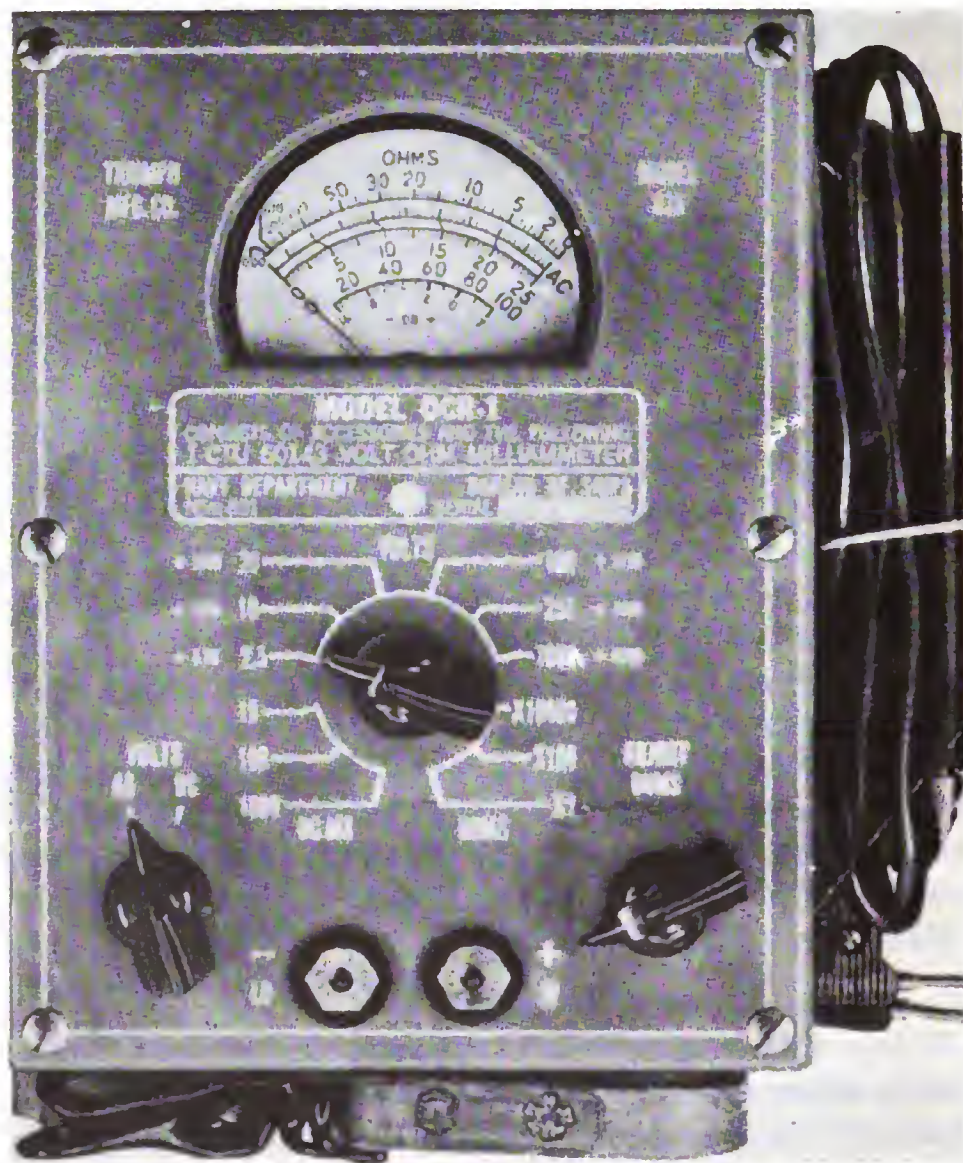


Figure 2-5.—Model OCR-1 multimeter.



not produce any useful indication. In order to measure alternating current with the multimeter, a small rectifier is used. The pulsating d-c output of the rectifier is measured by the meter. Although the meter torque is proportional to the average value, rather than the effective value of current and voltage, meter scales are usually calibrated at the factory to indicate effective values of current and voltage. A diagram of a simple a-c meter of this type is shown in figure 2-6.

The meter rectifier is usually of the metallic-oxide type, and is effective at power and audio frequencies. It has

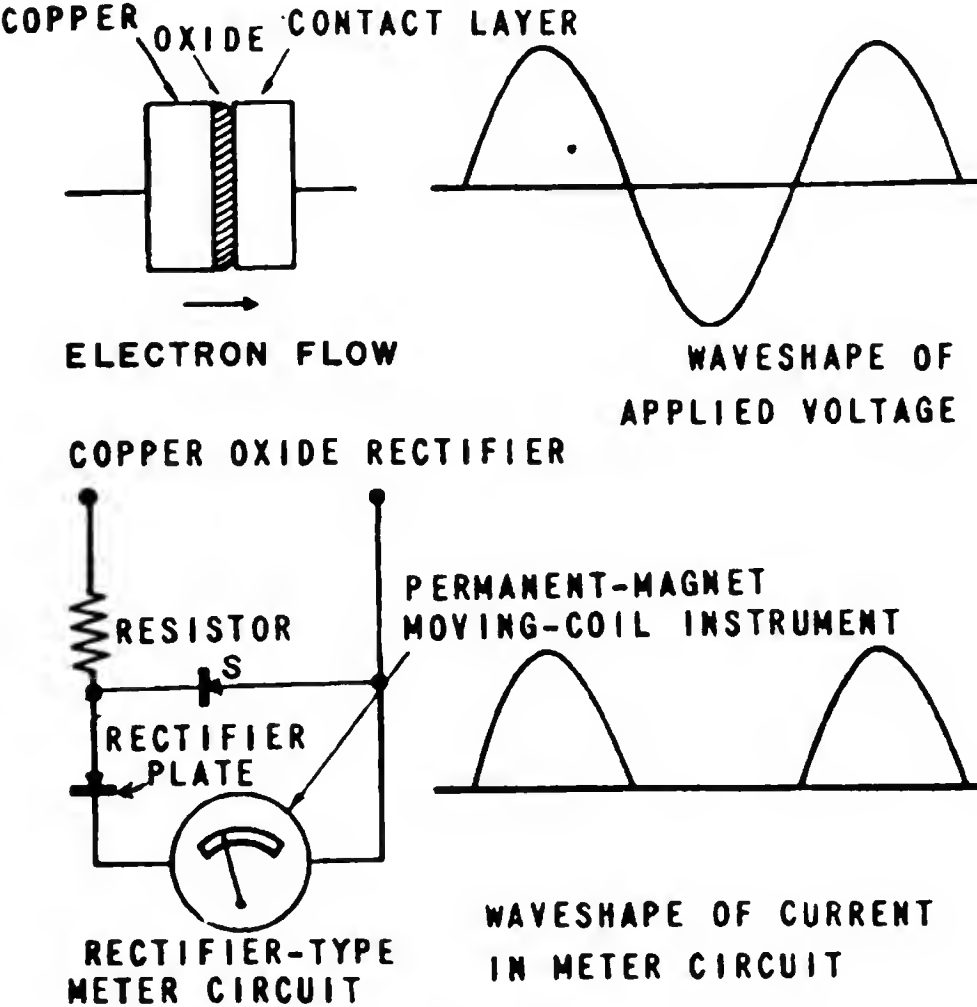


Figure 2-6.—A-c voltmeter.

objectionable error at radio frequencies. This disadvantage is caused by capacitance associated with the rectifier which bypasses the higher frequencies.

The shunt rectifier indicated at *S*, in figure 2-6, provides a high ratio of forward to leakage current and tends to keep the needle from vibrating.

## THERMOCOUPLE METERS

The bypassing action of the metallic-oxide rectifier can be eliminated entirely by using a thermocouple to obtain the d-c voltage to actuate the meter movement. When two dissimilar metals are joined together and the junction heated, a d-c potential is present across the cold ends of the metals. The potential depends on the difference in temperature between the hot junction and the cold terminal of the thermocouple. It makes no difference whether the heat is produced by direct current, audio-frequency

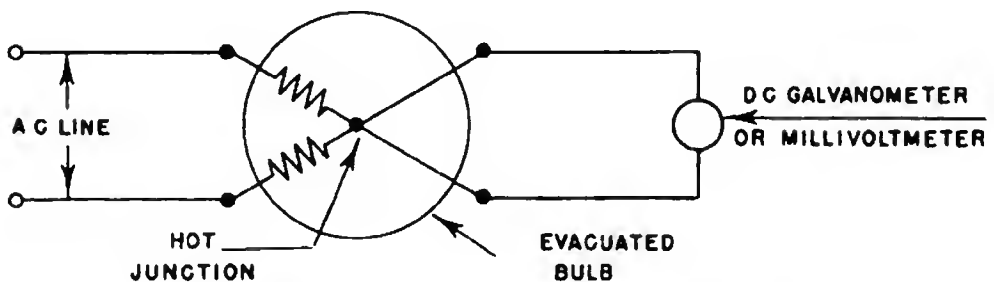


Figure 2-7.—Vacuum-type thermocouple.

current, or radio-frequency current. Thermocouples are usually enclosed in an evacuated bulb to reduce the time lag caused by the heating and cooling of the air around them. A vacuum-type thermocouple is shown in figure 2-7.

## VACUUM-TUBE VOLTMETER

The ordinary voltmeter has several disadvantages that make it practically useless for measuring voltages in high impedance circuits. For example, suppose that the plate voltage of a pentode amplifier is to be measured (figure 2-8, A). When the meter is connected between the plate

of the vacuum tube and ground, the meter current constitutes an appreciable part of the total current through the load resistor  $R_L$ . As a result, an incorrect meter reading is obtained. Because of the shunting effect of the meter on the pentode, the plate voltage decreases as the current through the load resistor  $R_L$  increases.

The circuit shown in figure 2-8, B, is a simple voltage divider with the 100,000 ohms effective resistance of the pentode in series with the 100,000 ohms resistance of the plate load resistor. This combination is connected across

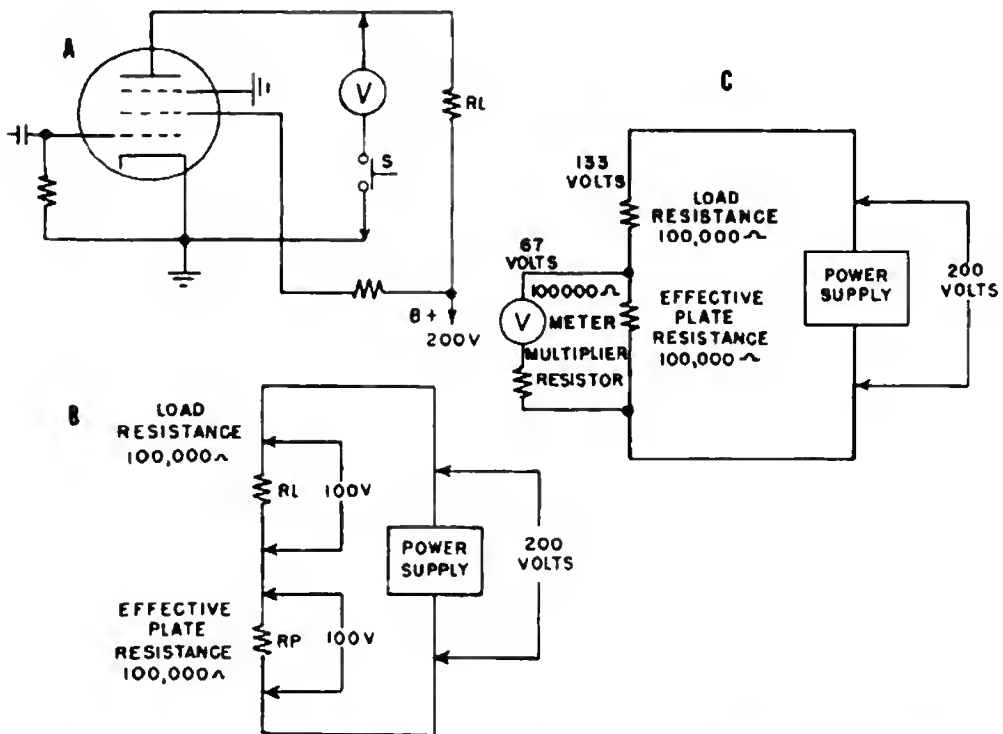


Figure 2-8.—Voltmeter error. A, Connection, B, equivalent circuit without meter, C, equivalent circuit with meter.

the power supply of 200 volts. Thus, before the voltmeter is connected across the pentode, the total current through  $R_L$  is

$$I = \frac{E}{R} = \frac{200}{200,000} = 0.001, \text{ or 1 milliampere.}$$

Connecting the voltmeter across the pentode increases the current through RL by decreasing the total resistance of the circuit (figure 2-8, C). If the sensitivity of the voltmeter is 1000 ohms per volt and its range is 0 to 100 volts, the resistance of the meter is 100,000 ohms. The total resistance of the parallel circuit formed by the pentode and the voltmeter is 50,000 ohms. This is in series with the 100,000-ohm load resistor. The total resistance of the series parallel combination is therefore 150,000 ohms. The total current in the load resistor is

$$I = \frac{E}{R} = \frac{200}{150,000} = 0.00133, \text{ or } 1.33 \text{ ma.}$$

The voltage across the plate load resistor is

$$E = IR = 0.00133 \times 100,000 = 133 \text{ volts.}$$

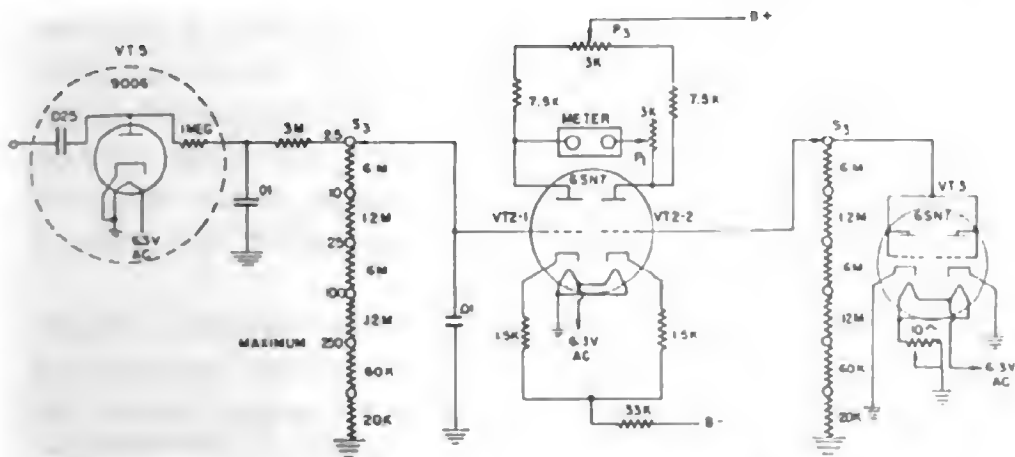
The voltage across the pentode is  $200 - 133 = 67$  volts. Thus, when the voltmeter is connected across the pentode plate, its indication is 67 volts. This is 33 volts less than the value existing across the pentode when the meter is not connected. The additional current drawn by the meter redistributes the voltages across the pentode and the load resistor. The voltage is changed from 100 volts across each to 67 volts across the pentode and 133 volts across the load resistor. This is an error of 33 volts caused by the voltmeter.

A meter with a sensitivity of 20,000 ohms per volt and a 100-volt range has a resistance of 2 megohms and a maximum current (full-scale deflection) of 50 microamperes. This current is small with respect to the current in the pentode circuit. Such a meter would indicate approximately 100 volts when connected across the pentode plate to ground. However, in circuits where very high impedances are encountered such as grid circuits of vacuum tubes, even a meter of this sensitivity would be useless because of the loading effect it imposes on the circuit.

Another limitation of a D'Arsonval a-c voltmeter has already been mentioned. This is the shunting effect at high frequencies of the relatively large meter rectifier capacitance. In certain vacuum-tube voltmeters this shunting effect is eliminated by replacing the usual metallic-oxide rectifier with a vacuum-tube amplifier in which the plate circuit contains the d-c meter and the voltage to be measured is applied to the grid circuit. Such a device is called a **VACUUM-TUBE VOLTMETER**. Voltages at frequencies up to and greater than 100 megacycles can be measured accurately with a vacuum-tube voltmeter. The input impedance is large. Therefore, the current drawn from the circuit whose voltage is being measured is small and in most cases negligible.

### Model OBQ-1 Multimeter

The OBQ-1 vacuum-tube multimeter can measure a-c and d-c voltages as well as resistance and current. This



**Figure 2-9.—A-c vacuum-tube voltmeter section of the OBQ-1.**

meter can be used to measure grid voltages of r-f and i-f amplifiers and a-v-c voltages without disturbing the circuits to which it is connected.

**A-C VACUUM-TUBE VOLTMETER SECTION.**—A schematic diagram of the a-c vacuum-tube voltmeter is shown in

figure 2-9. The signal to be measured is first rectified by the diode in the probe. The signal must be rectified because the meter circuit is sensitive only to d-c voltages. An R-C network in the probe filters the output of the rectifier tube. The d-c voltage is applied across a voltage-divider network. Notice that, even though range switch S3 is changed, the total input impedance (of the voltmeter) remains constant.

Even when no signal is applied to the plate of diode VT5 in the probe, a potential exists between the cathode and plate. This is called CONTACT POTENTIAL. In the absence of a positive plate supply source it makes the plate negative with respect to the cathode. The negative potential is present at the grid of VT2-1. To equalize the voltages on the VT2-1 grid and the VT2-2 grid, a compensating potential is introduced from tube VT3 to the grid of VT2-2. The contact potential on the grid of VT2-1 changes as the range switch is changed. To compensate automatically for this change, a voltage-divider is placed across VT3. A second arm on the selector switch changes the contact potential on the grid of VT2-2 to match that on the grid of VT2-1. This automatic compensation eliminates manual zero readjustment when the range switch is changed. The small variable resistor in the filament of VT3 is an internal control for adjusting the contact potential when the tube is replaced.

The meter circuit is a balanced bridge network. When the input voltage applied between the probe and ground is zero, the bridge is balanced and the voltages across the two arms containing the plate load resistors of VT2 are equal. Thus, the d-c meter indicates zero.

To offset aging of the twin triodes or small differences between the two sections of the tube, a zero adjustment (potentiometer P3) is provided to obtain an exact balance of the bridge circuit. The voltage being measured upsets the balance of the bridge and causes current to flow through the meter. The meter actually measures the

peak a-c voltage, but it is calibrated in rms values. The input impedance at the a-c terminals of the probe is high. At the lower frequencies the input capacitance is unimportant. As the frequency increases, the input capacitance introduces an additional load on the circuit under test and causes errors in the meter reading.

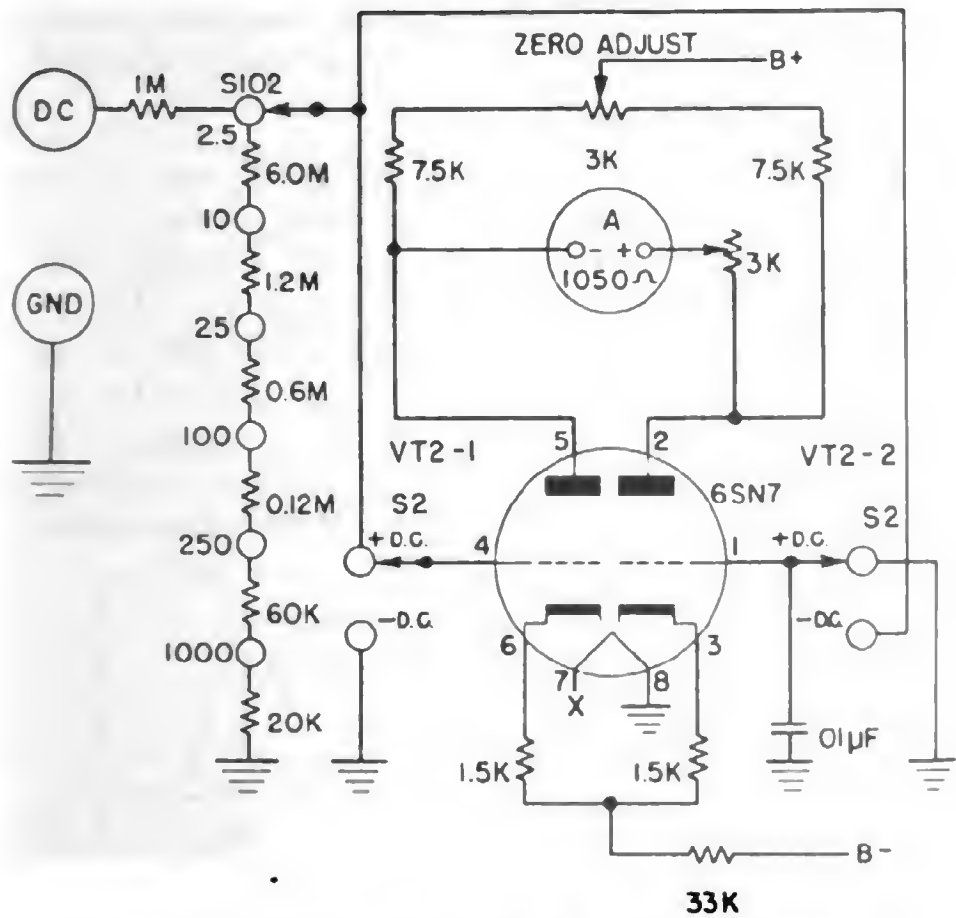


Figure 2-10.—D-c vacuum-tube voltmeter section of the OBQ-1.

**D-C VACUUM-TUBE VOLTMETER SECTION.**—The d-c voltmeter section of the OBQ-1 is shown in figure 2-10. When the meter is used to measure d-c voltages, the diode rectifier probe is not needed. Without the diode no contact potential is encountered and VT3 is switched out of the circuit. However, the meter remains in the original bridge

circuit. Any input to the voltage divider in the grid of VT2-1 unbalances the bridge and causes the meter to deflect. Switch S2 is used to change the polarity of the meter, thereby eliminating the necessity of reversing the test leads. The input impedance of the d-c voltmeter is 9 megohms over its entire range. It is not necessary to select the highest range when measuring an unknown voltage because overloads for a short time cannot damage the meter movement. Overloads for a long period of time may damage VT2.

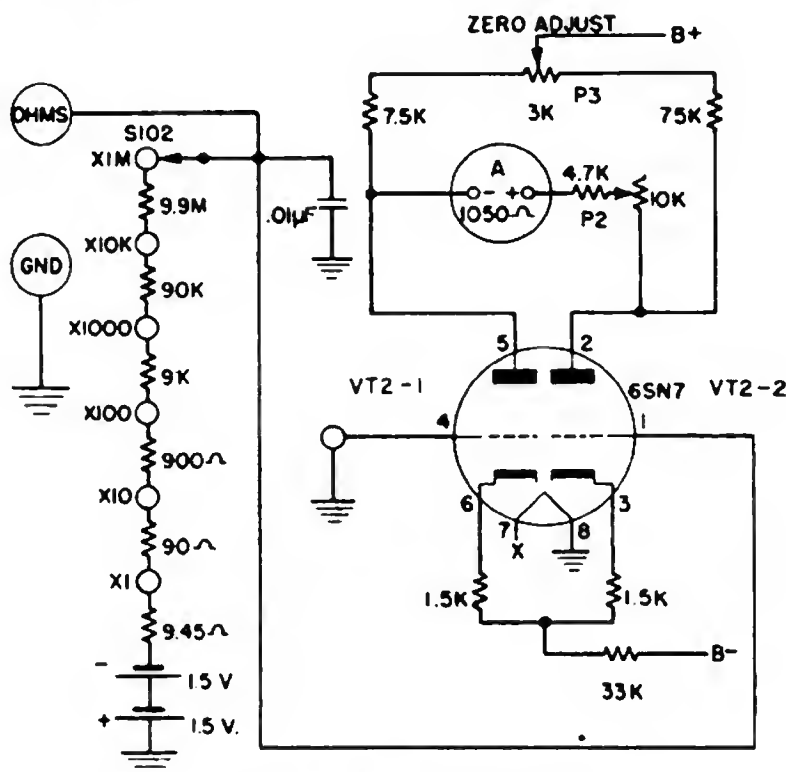


Figure 2-11.—Ohmmeter section of the OBQ-1.

**OHMMETER SECTION.**—A schematic of the ohmmeter section of the OBQ-1 is shown in figure 2-11. Tube VT2 is used in the same balanced bridge circuit with the grid of VT2-1 grounded. When the probes are open, a negative potential of 3 volts is applied to the grid of VT2-2 through the series resistance of the voltage divider. This



unbalances the bridge circuit. The unequal grid voltages cause sufficient potential difference between the plates of VT2 to give a full-scale deflection on the meter. This deflection represents infinity ohms. When the negative voltage on the grid of VT2-2 is removed by shorting the test leads, the grid is grounded and the bridge becomes balanced. Thus, for the condition of zero resistance, the meter deflection is zero.

Zero adjustment is made with potentiometer P3. Rheostat R2 is used to adjust the meter deflection to infinity ohms when the test leads are open. When an unknown resistance is placed between the ohms connection and ground, the bias voltage on the grid of VT2-2 decreases in proportion to the unknown resistance. The value of the unknown resistance determines the amount of unbalance and hence the magnitude of the meter deflection. The scale is calibrated in ohms. A suitable range is chosen with the range selector switch in order to provide approximately a one-half scale deflection. This insures sufficiently accurate indications.

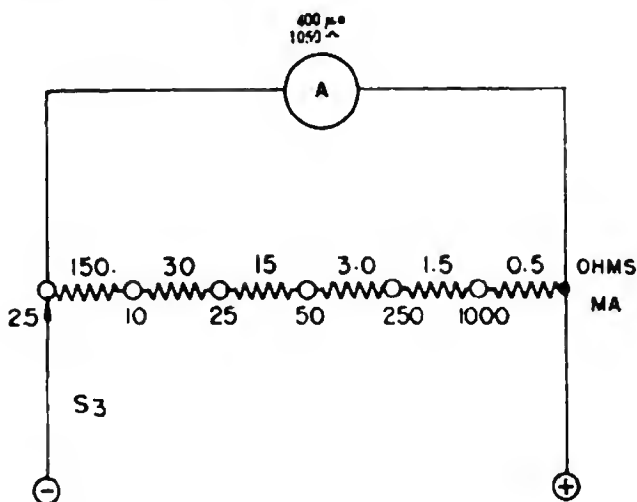


Figure 2-12.—D-c milliammeter section of the OBQ-1.

**MILLIAMMETER SECTION.**—Figure 2-12 shows a schematic of the d-c milliammeter circuit of the OBQ-1. This

circuit uses a conventional switching arrangement with shunts to increase the range of current measurement. As the tap is moved toward the positive terminal, the value of the shunt resistance is reduced and the range is thereby increased. The range switch is so arranged that, in changing from one position to the next, the meter is protected by an uninterrupted shunt circuit like that shown in figure 2-3, B. The resistors that do not shunt the meter are placed in series with it. This arrangement eliminates the removal of the shunt protection when the range switch is changed from one position to another as shown in figure 2-3, A.

## **TUBE TESTERS**

### **Principles**

Each vacuum tube purchased by the Navy has been thoroughly tested electrically and mechanically. Nevertheless, it is possible for tubes to be damaged in shipment, storage, or handling. It is a good rule to test a tube before using it.

Vacuum tubes do not last indefinitely. Coated cathodes lose their power to emit electrons because the cathode coating flakes off. Impregnated emitters of filament-type tubes become depleted with age. Defective seals permit air to leak into tubes and "poison" the emitting surface. Vibration or excessive voltage causes internal shorts or opens. Whenever radio equipment operates subnormally, one of the first maintenance procedures is to check the tubes with a tube tester.

### **Types of Testers**

Two kinds of tube testers are in general use. One kind uses the tube emission to indicate the condition of the tube. The second kind measures the dynamic mutual conductance of the tube to indicate the operation of the tube.

The end of the useful life of a tube is usually preceded

by a reduction in electron emissivity—that is, the cathode no longer supplies the number of electrons necessary for proper operation of the tube. In the emission tester the proper voltages are applied to each electrode in the tube. A meter indicates the plate current. If the tube has an open element or is at the end of its useful life, the emission tester gives an indication of this defect in the REJECT portion of the scale.

It is possible for a tube to show normal emission and still not operate properly. The reason for this is that the tube efficiency depends on the ability of the grid voltage to control the plate current. The emission tester tests only the plate current and not the ability of the grid to control the plate current. The mutual-conductance tube tester, however, measures the grid-plate transconductance and indicates the operation of the tube, not merely the condition of the emitting surface.

The terms “mutual conductance” and “transconductance” are used interchangeably in many texts. The Navy Department prefers transconductance, but commercial tube testers are marked “mutual conductance.”

When the prefix “dynamic” accompanies the term, as in “dynamic mutual conductance” or “dynamic transconductance,” the meaning includes the effect of load impedance in the plate circuit of the tube being tested. The dynamic characteristic is not the same as the tube static characteristic because, when a load impedance is present, the voltage at the plate of the tube differs from the voltage of the plate supply by the drop in the load impedance. Thus, when the signal is on the positive half cycle, the plate current increases. This causes an increase in the voltage drop in the plate load impedance which reduces the potential actually applied to the plate to a value somewhat less than the plate voltage at the operating point. During the negative half of the cycle, the plate current decreases and the voltage drop in the

plate load impedance is reduced. This causes the plate voltage to rise to a value somewhat higher than that at the operating point. The dynamic characteristic is therefore the characteristic of the tube in operation. The difference between the dynamic and static characteristic lies in the plate load impedance.

The static characteristic of a tube involves a change in two of three quantities, the third being held constant. Thus, the transconductance of a triode is the change in plate current divided by the corresponding change in grid voltage, the plate voltage remaining constant. The dynamic transconductance is the change in plate current divided by the corresponding change in grid voltage, when a plate load impedance exists in the plate circuit and the plate voltage is permitted to swing.

Most tube testers, other than the emission type, test the dynamic characteristic by placing the tube in a working circuit. Very often the prefix "dynamic" is omitted for the sake of brevity. If "dynamic" is omitted, the reader may identify the meaning by looking for the plate load impedance in the tube circuit under test. If the plate load impedance is used, the characteristic being obtained is DYNAMIC.

Dynamic mutual conductance,  $g_m$ , in micromhos or grid-plate dynamic transconductance is defined as the resultant change in a-c plate current  $\Delta I_p$  divided by the applied change in a-c grid voltage  $\Delta E_g$ . The value of  $g_m$  is a good indication of amplifier-tube performance because it shows the effectiveness of a tube in converting a small change in grid voltage to a large change in plate current.

Conductance is the reciprocal of resistance, that is, the ratio of current to voltage. The word "mutual" means "pertaining to both of two things" and refers to both plate and grid. The unit of conductance is the MHO, which is the word "ohm" spelled backward. For convenience, a

millionth of a mho, or MICROMHO, is the commonly used unit of transconductance.

The equation of transconductance is

$$g_m = \frac{\Delta I_p}{\Delta E_g}.$$

In a tube tester, the a-c signal voltage  $\Delta E_g$  is always a constant value. The meter indicates the change in plate current  $\Delta I_p$ , and is calibrated directly in micromhos. For example, if a 1-volt rms signal on the grid produces a 3-milliampere rms plate current, the 3-milliampere deflection can be marked 3000 micromhos, since

$$g_m = \frac{0.003}{1} = 0.003 \text{ mho} = 3000 \text{ micromhos}.$$

The scale of mutual-conductance tube testers is calibrated in micromhos.

Tube testers usually provide tests for shorts, noise, and gas, in addition to the quality test. However, the interelectrode capacitance is a factor not checked on standard tube testers. Interelectrode capacitances of tubes are important, when tubes are used in high-frequency circuits. When tubes are replaced in a high-frequency circuit, the circuit may be detuned because the interelectrode capacitances vary from tube to tube of the same type. It is not advisable, therefore, to replace a large number of tubes in a high-frequency circuit without checking their effect on the circuit, one tube at a time. In any complicated circuit it is bad practice to arbitrarily replace a large number of tubes. It is better to replace them either tube by tube or in small groups.

### Tube Tester I-177

Tube tester I-177 is a transconductance tube tester used in the Navy as an individual unit or as a part of test set I-56-K. Figure 2-13 is a picture of the tube tester I-177 with the cover raised. Figure 2-14 is the



**Figure 2-13.—Tube tester I-177.**

schematic diagram of this tube tester. The diagram as a whole looks complicated, but it is easily understood by considering one at a time the following individual circuit tests: (1) Line test, (2) short test, (3) noise test, (4) gas test, (5) rectifier test, and (6) quality test.

The potentials for testing a tube are obtained by setting the controls on the upper panel of the tester. A chart listing the settings for each type of tube is supplied with the tube tester. The controls must be adjusted before the tube is inserted in the tube tester in order to prevent the tube from burning out.

**LINE TEST.**—The line test is the first test made after a tube is inserted in the tester. Pushing the **LINE TEST** but-







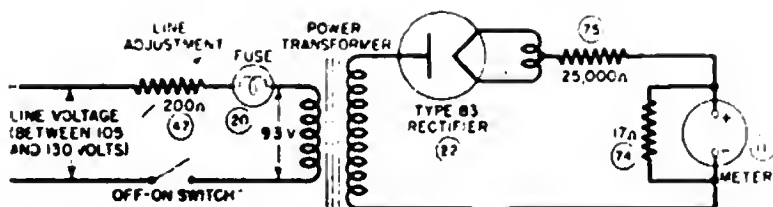


Figure 2-15.—Simplified line-test circuit.

ton connects the meter of the tube tester so that it indicates the B-supply voltage of the tester, as shown in figure 2-15. The tester is so calibrated at the factory that the meter pointer is exactly at 1500 (near the center of the scale) when the voltage across the primary is 93 volts.

Tubes of different types draw different amounts of current when under test. The LINE ADJUSTMENT rheostat 47, in series with the primary of the power transformer, is adjusted until the meter reads 1500. When the meter is adjusted to this point, the primary voltage of the transformer is 93 volts, the value at which the instrument was designed to operate.

Setting the LINE ADJUSTMENT control provides the correct voltages to the instrument. A small automobile-type lamp, labeled 20 on the diagram, in series with the primary of the transformer serves as a fuse to protect the entire instrument from excessive overload. It will burn out during an overload.

**SHORT TEST.**—A simplified schematic diagram of the short-test and the noise-test circuits is shown in figure 2-16. Turning the SHORT-TUBE TEST switch through positions 1, 2, 3, 4, and 5 connects various pairs of tube electrodes in turn across the test terminals of the circuit. Tubes having shorts between elements complete a circuit that applies the a-c voltage across resistor 79 to the neon SHORTS lamp 19. This causes it to glow. There is an intermittent flash of the neon lamp when the switch is turned. An intermittent flash may be caused also by an intermittent short in the tube under test. The noise test

is used to check for intermittent shorts or microphonic noise.

**NOISE TEST.**—The circuit shown in figure 2-16 is used also for making a noise test of vacuum tubes. In testing for noise caused by intermittent shorts or a microphonic

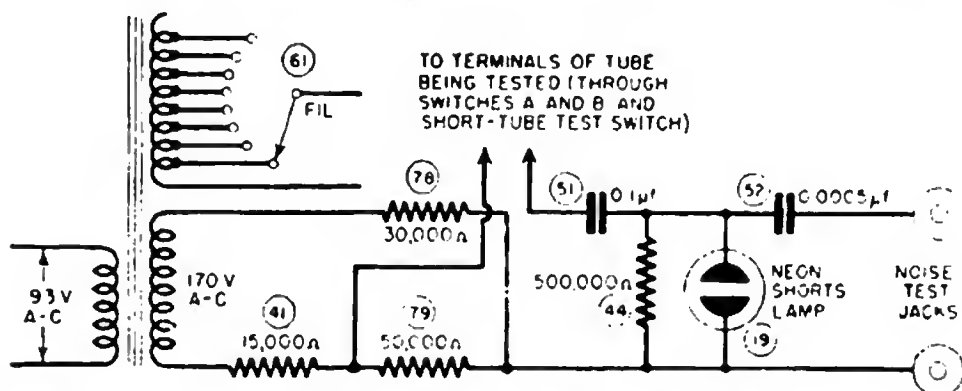


Figure 2-16.—Simplified schematic diagram of the short-test and noise-test circuits.

tube, the antenna and ground terminals of a radio receiver are connected to the NOISE TEST jacks. Any intermittent short between tube electrodes permits the a-c voltage from the power transformer to be applied momentarily to the neon lamp. The brief oscillation of the neon lamp contains radio frequencies that are reproduced as an audible signal in the receiver speaker. The tube under test should be tapped gently while testing for noise or intermittent shorts.

**GAS TEST.**—The presence of gas in a vacuum tube is checked by means of the circuit shown in figure 2-17. A

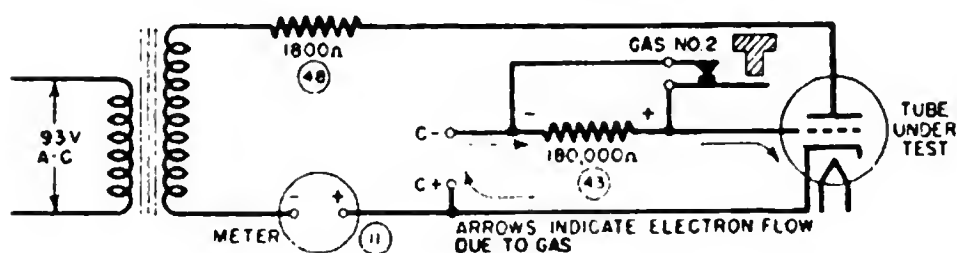


Figure 2-17.—Simplified gas-test circuit.

button marked "GAS NO. 1" (not shown in figure 2-17) is first pressed. Pressing this button applies the proper amount of plate and grid voltages to the tube under test and causes a definite value of plate current to flow. Pressing the button marked "GAS NO. 2" inserts the 180,000-ohm resistor 43 in the grid circuit. If gas is present in the tube, grid current flows as shown by the arrows in figure 2-17. The grid current caused by the gas develops a voltage across resistor 43. This reduces the normal bias and increases the plate current measured by the meter. A tube with a negligible amount of gas produces an increase in plate current of less than one scale division when "GAS NO. 2" button is pressed. An increase of more than a division indicates excessive gas in the tube.

**RECTIFIER TEST.**—The circuit shown in figure 2-18 is used for making emission tests of full-wave rectifiers, diodes, and cold-cathode (OZ4) tubes. An a-c voltage is applied across the tube under test. The meter indicates

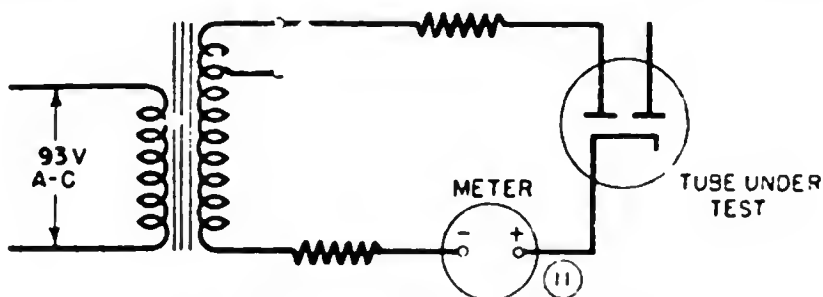


Figure 2-18.—Simplified rectifier-test circuit.

the resultant rectified current. The two sections of a full-wave rectifier are tested separately. The button for testing OZ4 cold-cathode rectifier tubes provides a higher a-c voltage than is used for heater or filament-type rectifiers. The button for diodes provides a lower voltage than for regular rectifiers and inserts a protective series resistance.

**QUALITY TEST FOR AMPLIFIER TUBES.**—For the RED-GREEN quality test based on the dynamic mutual conduct-

ance, or for direct measurement of the dynamic mutual conductance, the proper d-c grid bias for the tube under test is supplied by the type-5Y3G rectifier tube (figure 2-19). Setting potentiometer  $R$  at the value called for

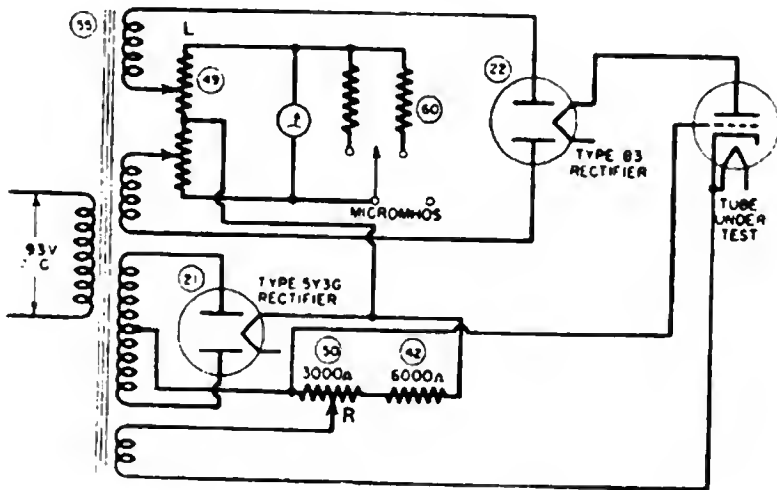


Figure 2-19.—Simplified quality-test circuit.

on the test-data card adjusts the d-c bias to the correct value.

An a-c voltage of 4.7 volts rms is obtained from a separate winding on the power transformer and is applied in series with the grid bias. This voltage alternately swings the grid in positive and negative directions from the d-c bias, thereby producing the grid-voltage change  $\Delta E_g$  required for a dynamic mutual-conductance test.

The plate voltage for the tube under test is supplied by the type-83 rectifier tube. The meter that measures the plate-current change  $\Delta I_p$  is in the return circuit of the rectifier supply. A dual potentiometer  $L$  is shunted across the meter. Setting control  $L$  on the panel adjusts the shunt resistance so that the meter pointer gives an indication either in the GREEN section of the scale (if the tube is not defective) or in the RED section (if the tube is defective). The MICROMHOS switch places shunt resistors across the meter, as required for the three scale ranges.

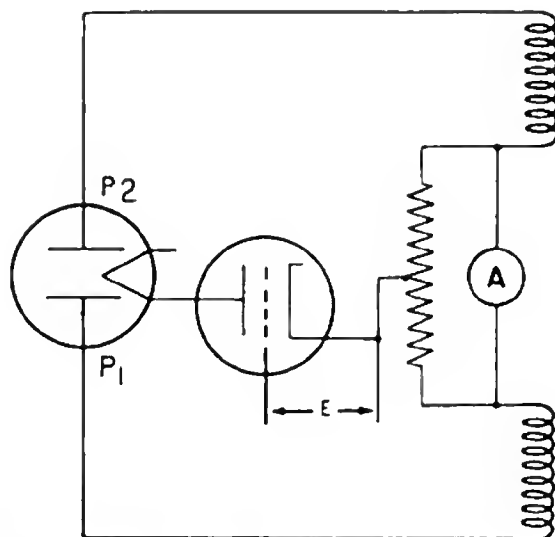


Figure 2-20.—Simplified schematic diagram of meter circuit for quality test.

For the quality test the meter is connected as shown in figure 2-20. When a fixed d-c bias  $E$  is applied the tube has a fixed value of effective resistance. The full-wave rectifier conducts equally on adjacent half-cycles. The meter needle tends to deflect equally on each side of zero (center position) but cannot follow variations at the power-line frequency, hence remains at zero.

When an a-c signal is applied in series with the d-c bias, the grid voltage swings alternately in a positive and then a negative direction. This increases and then decreases the plate current at the power-line frequency in accordance with the grid signal. The voltage drops across the two sections of the resistor become unbalanced because the plate currents during the two successive alternations are unequal. The deflecting force on the meter is thereby unbalanced and the indication is no longer zero. The meter indicates a value proportional to the increase in plate current. The calibration is in units of dynamic mutual conductance.

## QUIZ

1. What determines the value of series resistance of a voltmeter?
2. How is the sensitivity of voltmeters expressed?
3. How is the current-measuring capacity of a D'Arsonval meter movement extended?
4. Why is an ordinary voltmeter undesirable for measuring voltages in high-impedance circuits?
5. What are the two main advantages of a vacuum-tube voltmeter?
6. What are the two types of tube testers in general use?
7. What is the equation for transconductance?
8. Pushing the line test button in the tube tester I-177 indicates what voltage?
9. What is the function of the small automobile-type lamp in series with the primary of the transformer of the I-177 tube tester?
10. Tubes having shorts between elements in the I-177 tube tester complete what circuit to cause the neon SHORTS lamp to glow?
11. Upon what function of a gassy tube is the indication dependent in the I-177 tube tester?
12. In figure 2-20, for the quality tube test, if  $E$  is a steady d-c bias why will  $A$  indicate zero?
13. If a 60-cycle a-c voltage is introduced in series with the bias voltage,  $E$ , in the quality tube test (figure 2-20) why will the meter indicate a reading?

## TEST EQUIPMENT—ANALYSIS

### CATHODE-RAY OSCILLOSCOPE

#### *Cathode-Ray Tube*

The cathode-ray tube is a special type of vacuum tube in which a fast-moving stream of electrons is formed into a narrow beam and allowed to strike a chemically-treated screen. When the electrons strike the screen they cause the chemical coating to fluoresce or glow. The chief use of the cathode-ray tube is to provide a visual means of examining waveforms encountered in electric circuits. The beam electrons have very little inertia and may be deflected quickly. This permits fast amplitude changes of the order of a few millionths of a second. The cathode-ray tube is used to measure the amplitude and duration of waveforms at frequencies much higher than those which can be measured by any other type of indicating device.

**SIMPLE ELECTROSTATIC CATHODE-RAY TUBE.**—A simple cathode-ray tube is shown in figure 3-1. This cathode-ray tube represents a very early step in the development of the more complex tubes in use today. The cathode is heated to a high temperature in order to emit electrons from its surface. Electrons have a negative charge. Since unlike charges attract, the electrons proceed toward the anode, which is at a high positive potential. Most of them

strike the anode and cause a current in the external circuit. However, some electrons pass through the small opening in the anode and, without much loss in velocity, continue on to the screen where their impact causes a fluorescent spot. The electrons striking the screen travel at high velocity. This simple type of cathode-ray tube has little practical use today.

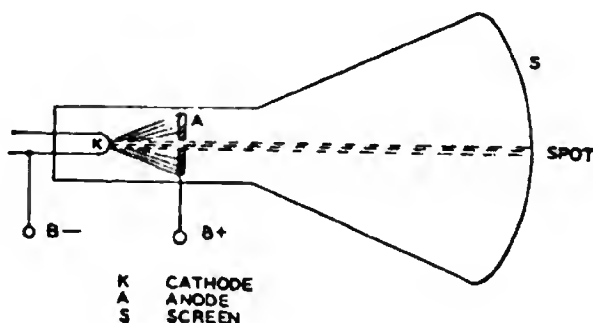


Figure 3-1.—Simple electrostatic cathode-ray tube.

**ELECTROSTATIC CATHODE-RAY TUBE.**—The modern cathode-ray tube contains elements which permit the electron beam to be focused, deflected either vertically or horizontally, and changed in intensity. A cathode-ray tube with these elements is illustrated in figure 3-2.

A small nickel cylinder comprises the cathode. Unlike the directly-heated type used in the simpler tubes, this cathode is indirectly heated and has an oxide coating. The oxide coating provides for the evaporation of a sufficient supply of electrons at a comparatively low temperature. The direction of the emission is limited to that end of the cathode facing the anodes because only that end has the oxide coating. The heater is noninductively wound in order to minimize the effect of its magnetic field on the electron beam.

The heart of the cathode-ray tube is the **ELECTRON GUN** (figure 3-3) composed of the heater, cathode, control grid, first anode, and second anode. This unit is so called



because of its gun-like action in shooting a stream of electrons toward the screen.

In early cathode-ray tubes there was little control of either the number or the direction of the electrons emitted by the filament. In modern tubes the number as well as the direction of the electrons is controlled by the cathode and its associated control grid. The control grid is cylindrical in form and fits over the cathode. The end nearest the anodes contains a plate with a small hole in it.

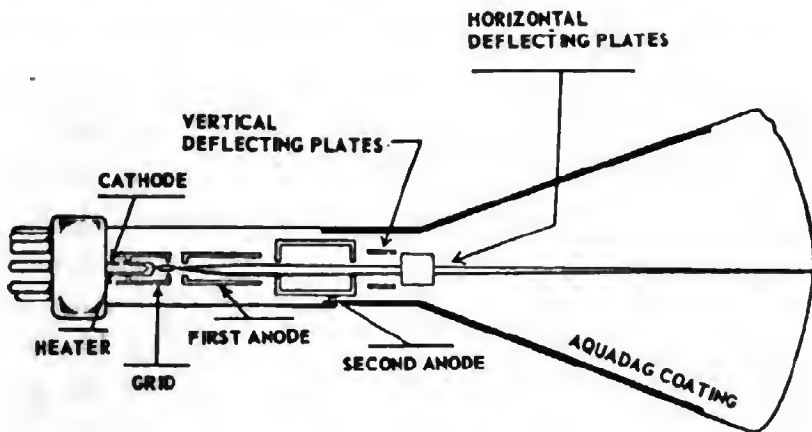


Figure 3-2.—Cathode-ray tube with electrostatic reflection.

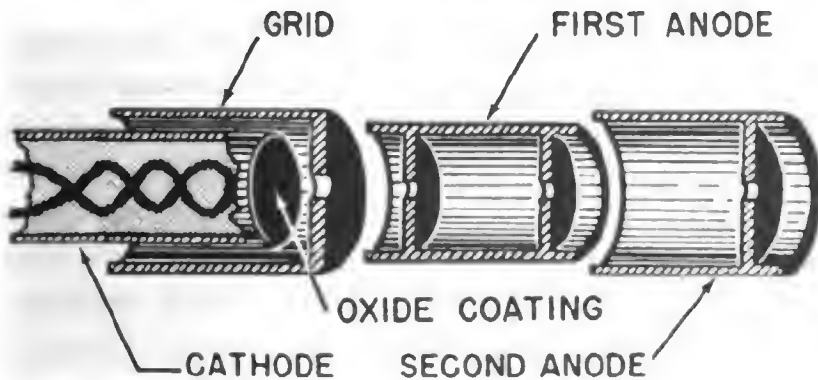


Figure 3-3.—Electron gun.

The control grid effectively controls the electron emission from the cathode and at the same time forces the electrons into a narrow beam as they pass through the small hole in the end of the grid. If the grid is made very

negative with respect to the cathode, all the electrons are repelled back to the cathode and none of them strike the screen.

The first anode is the focusing element of the electron gun. It concentrates the electrons and prevents them from scattering as they leave the control grid. Focusing is accomplished by operating the first anode at a positive potential with respect to the control grid and the second anode at a still higher positive potential. The difference in potential between the two anodes creates an electric field between them.

As the electrons emanate from the opening in the end of the control-grid cylinder, they are accelerated by the electric field between the first and second anodes. Instead of colliding with the first anode, the electrons move at high speed in the direction of the longitudinal axis of the tube. By the time they leave the electron gun through the opening in the first anode, their velocity is such that they traverse the length of the tube beyond the gun and strike the fluorescent screen with an impact that causes it to glow.

The greater the voltage across the first and second anodes, the greater the electrostatic field and the greater the velocity of the electrons traveling toward the screen. The focus control varies the voltage applied between the first and second anodes, establishing the correct polarity between them to produce a sharp clear spot on the screen. The intensity or brightness of the spot is controlled by varying the bias on the control grid with respect to the cathode.

In order to produce a pattern on the screen the electron beam must be deflected by two or more forces not acting in the same direction. In the electrostatic type, CRT, two sets of parallel plates mounted inside the tube at the outlet end of the electron gun provide a means of deflecting the beam horizontally and vertically.

An electron beam passing between two plates across which there is an electric field, is deflected toward the positive plate as indicated in figure 3-4. If the electrons

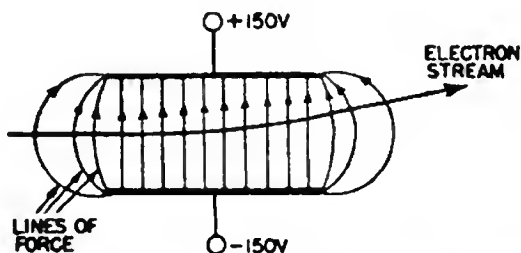


Figure 3-4.—Deflection of electron beam in an electrostatic field.

were slow-moving as they enter the field, they would travel directly to the positive deflecting plate and never reach the fluorescent screen. However, if they are shot into the deflecting field with sufficient velocity, their paths are bent in the direction of the positive plate. However, their inertia prevents their striking the plate.

The position of the spot for the condition of zero voltage across the deflecting plates is indicated in figure 3-5, A. The arrangements of battery potentials shown in figure 3-5, B, C, and D simplify the discussion. They do not necessarily represent a practical circuit. With the proper combination of voltages, the spot can be moved anywhere on the screen. If d-c voltages of the polarities indicated in figure 3-5, B, are applied simultaneously to both sets of deflecting plates, the spot moves to the position shown. Reversing the polarity of the voltage applied to the vertical deflecting plates moves the spot to the lower right portion of the screen (figure 3-5, C). In a similar manner the positions of the spot in figure 3-5, D and E, may be analyzed.

The amount of deflection depends mainly on two things —(1) the amplitude of the voltage or voltages placed on the deflection plates and (2) the speed of the electrons in the beam. The deflection depends to some extent on the distance of the deflection plates from the screen. If the

plates are moved farther from the screen, the deflection is greater for a given voltage. Because the spacing of the deflection plates in a given tube is fixed and the speed of the electrons as they leave the electron gun is fixed for a given accelerating potential, the movement of the spot on the screen depends only on the voltage applied to the deflection plates.

The amount that the electron beam is moved by a change of one volt across the deflection plates is called the DEFLECTION SENSITIVITY of the tube. For increased sensitivity the deflection plates are made longer so that the electrons remain in the electrostatic field for a longer

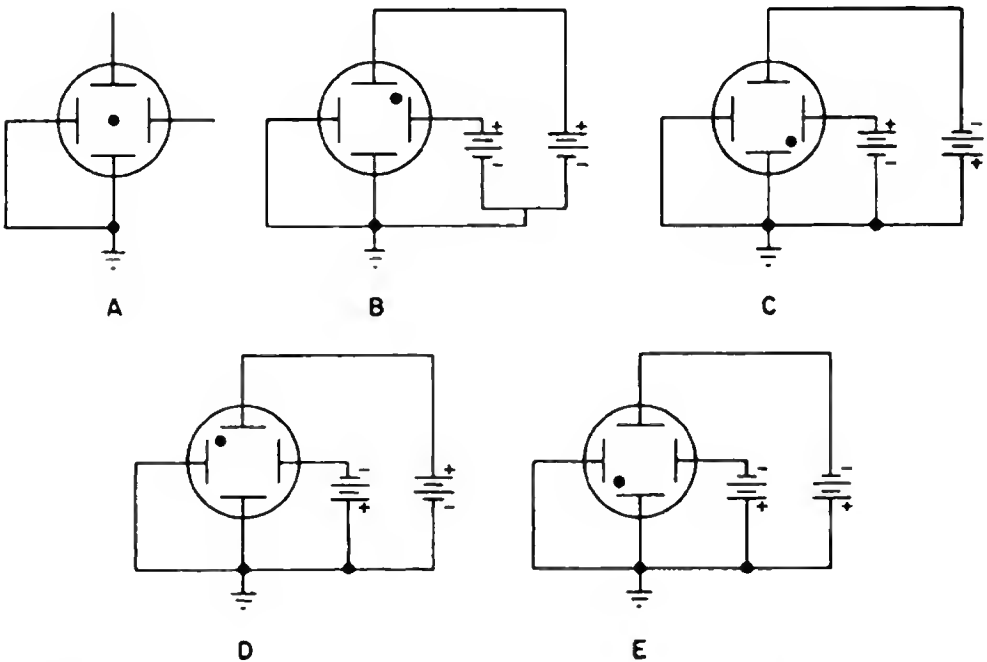


Figure 3-5.—Basic method of deflection in an electrostatic cathode-ray tube.

time. When the plates are lengthened, they are usually bent out toward the glass envelope. This bending of the plates is necessary to prevent the electron beam from striking the deflection plates at the condition of maximum deflection.

An aquadag coating is used in most cathode-ray tubes.

The aquadag coating is a graphite compound. It is applied to the inside of the glass envelope and connected to a high positive potential with respect to the cathode. As the electron beam strikes the fluorescent screen, electrons are knocked free from its surface. These electrons emitted from the fluorescent material are called SECONDARY ELECTRONS. These secondary electrons plus the cathode-ray electrons would soon make the screen highly negative with the result that the beam would be cut off. However, the positive aquadag coating attracts electrons to it. They are then returned to the power supply, thus eliminating the space-charge effect. Although it is positive with respect to the cathode, the aquadag coating is usually at ground potential and the cathode is made negative with respect to ground. The aquadag coating forms a shield to prevent external electric fields from disturbing the electron beam.

The fluorescent material used for the screens of cathode-ray tubes varies depending on the color of light and the persistence desired. All fluorescent materials have some phosphorescence or afterglow. The persistence is the duration of the afterglow after the electron beam is removed. Tubes can be made to produce any color of light with long, medium, or short afterglow by the proper selection of the screen material. The use for which the tube is designed usually determines the color and persistence desired.

### Theory and Operation

One of the most important pieces of test equipment used by the electronics technician is the cathode-ray oscilloscope. Using an oscilloscope provides a visual means of examining the operation of different circuits. This is accomplished with a cathode-ray tube.

**APPLICATIONS OF THE OSCILLOSCOPE.**—The oscilloscope is used to observe and to measure electrical quantities. It is the only method of observing and measuring wave-

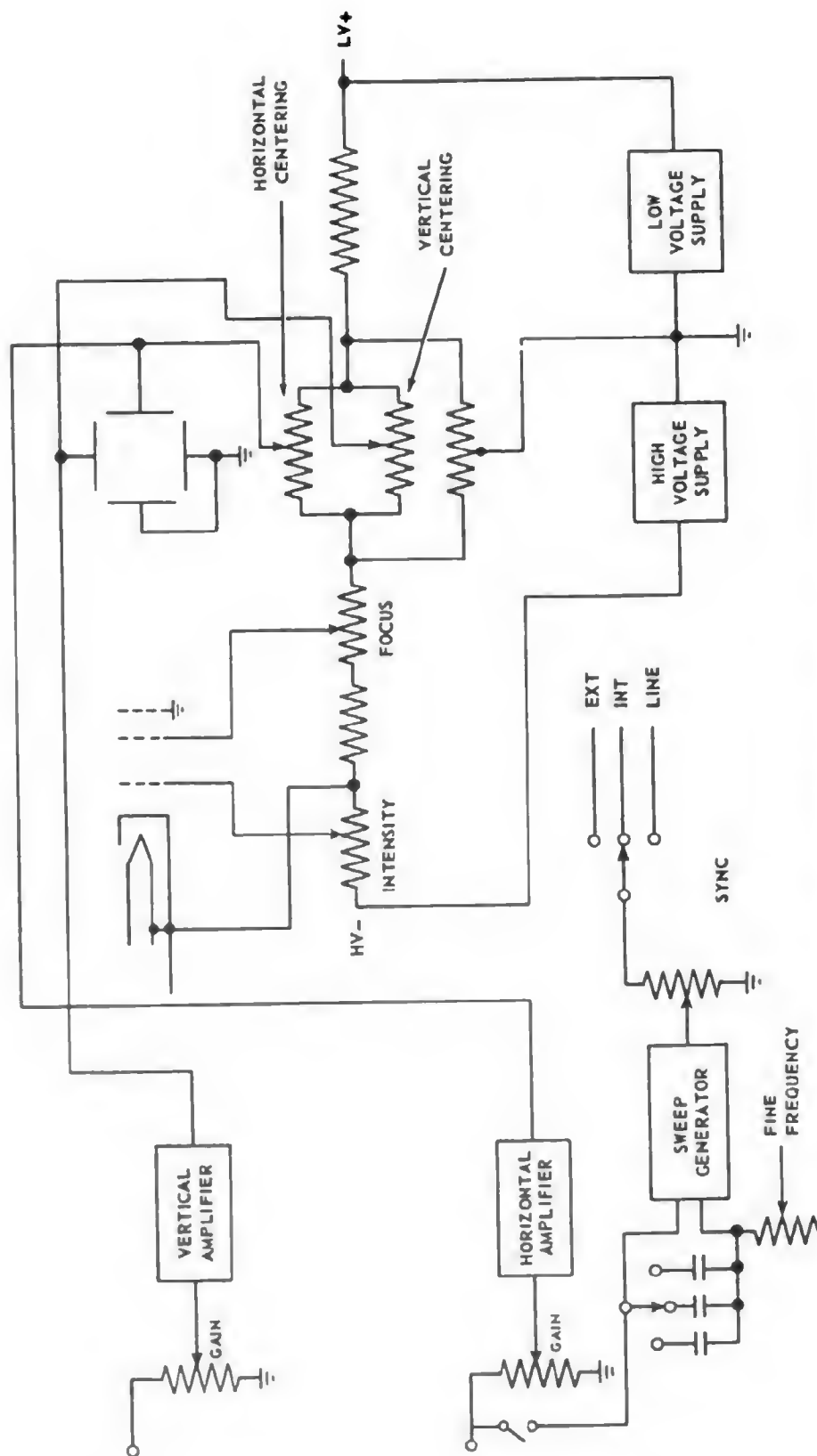


Figure 3-6.—Block diagram of a cathode-ray oscilloscope.

forms in certain pulsed equipment. The visual indication makes it easy to analyze conditions involving distortion, phase shift, ripple voltage, hum, and modulation. These are only a few of many possible applications. The oscilloscope may be used to measure current and voltage changes that occur in intervals as short as a small fraction of a millionth of a second. A block diagram of a simple oscilloscope is shown in figure 3-6.

Consider a cathode-ray oscilloscope whose vertical input is connected to a source of a-c voltage having a sine waveform. The screen presents a graph of this voltage similar to that shown in figure 3-7. The x-axis is the time base. The y-axis is a scale on which the instantaneous values of the voltage are plotted. To form a suitable time base a voltage of saw-tooth waveform is impressed on the horizontal deflection plates. This sweeps the electron beam from left to right across the screen at a constant rate of speed and then returns it quickly to the starting point at the left. In most cases the cycle is repeated with sufficient rapidity to form a continuous line. In the absence of the a-c voltage on the vertical plates this line appears straight and in a horizontal position. It forms the time base and its length represents a definite time interval. The voltage applied to the horizontal plates is called the SWEEP VOLTAGE because of its sweeping action on the

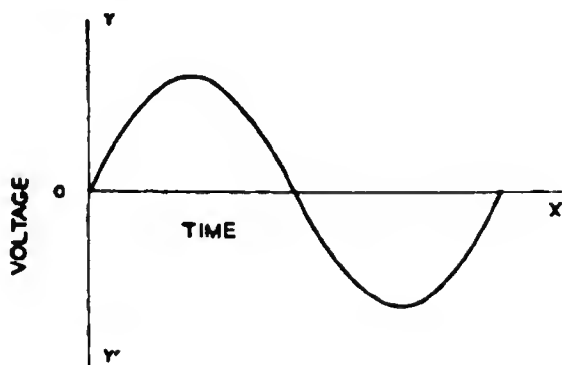


Figure 3-7.—Graph of sine-wave voltage plotted against time.

electron beam. The oscillator from which this voltage is derived is called the SWEEP GENERATOR.

**SWEEP GENERATOR.**—A simple sweep generator is shown in figure 3-8, A. The output voltage of this sweep generator varies between fixed limits, increasing at a constant rate and decreasing at a much faster rate to produce the saw-tooth waveform in figure 3-8, B.

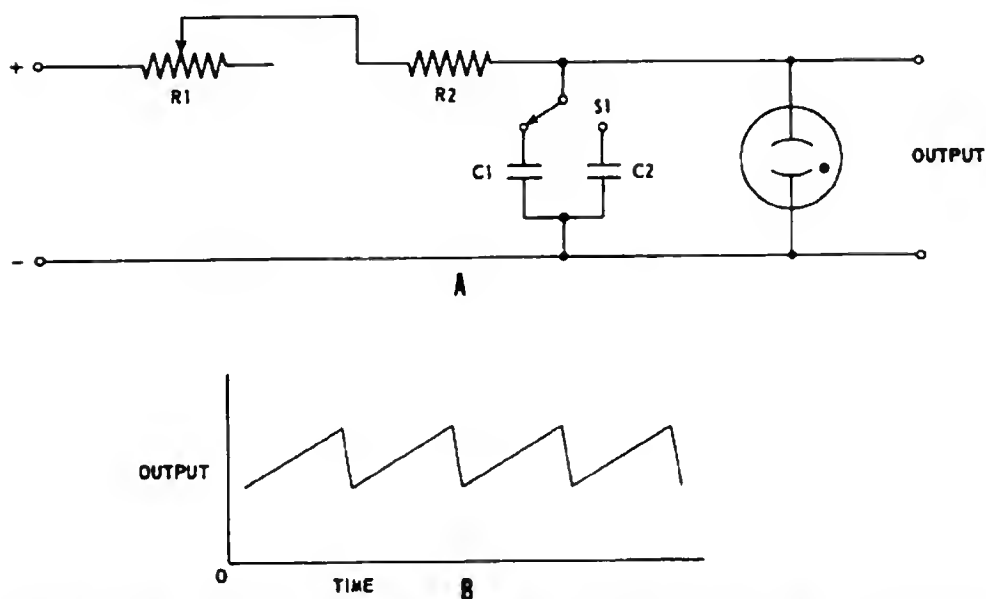


Figure 3-8.—Simple sweep generator. A, Schematic diagram, B, saw-tooth output voltage.

When a relatively high d-c potential is applied to the input terminals, capacitor  $C1$  or  $C2$  charges at a rate determined by the capacitance and resistance of the circuit. The neon bulb across the capacitor has no effect until the capacitor voltage rises to the critical ionization potential of the neon gas. At that time the bulb glows and its resistance falls to a low value. This permits the rapid discharge of the capacitor through the low resistance path which the bulb provides. Simultaneously, the capacitor voltage falls until the critical deionization potential is reached and the neon bulb stops glowing. The discharge path is thereby interrupted with the rapid rise



in the resistance of the neon bulb. The capacitor voltage begins to rise again and the cycle repeats.

The successful operation of the sweep generator depends on the fact that the voltage required to ionize the neon bulb is higher than that required to deionize it. Variable resistor R1 is used to adjust the sweep generator frequency within narrow limits. It is the fine frequency adjustment. Coarse frequency control is obtained with S1 by switching different values of capacitance into the circuit. In order to use the linear portion of the capacitor charging voltage curve the input d-c voltage is made large with respect to the ionization potential of the neon bulb, as shown in figure 3-9.

The capacitor discharge occurs during a brief interval called FLYBACK TIME. This is a very small part of the complete cycle, as shown in figure 3-9. The neon bulb sweep generator has disadvantages. The output frequency is not stable. Its range is limited because of the small difference between the ionization and deionization potentials.

The most common type of saw-tooth generator used in the cathode-ray oscilloscope employs a thyratron triode discharge tube like the one shown in the circuit of figure 3-10. An advantage of the thyratron over the neon bulb is the grid influence which permits the use of a more linear portion of the capacitor charging curve. This is true because the grid increases the difference between the firing and extinction potentials.

The sweep generator circuit in figure 3-10 is similar to the neon bulb type in figure 3-9. Switch S1 provides coarse frequency control and variable resistor R2 provides fine control. Resistors R4 and R5 form a voltage divider between the B + terminal and ground. The grid bias for the thyratron is developed across resistor R4 and the plate supply voltage, across resistor R5.

Capacitor C1 blocks any external d-c voltage from the

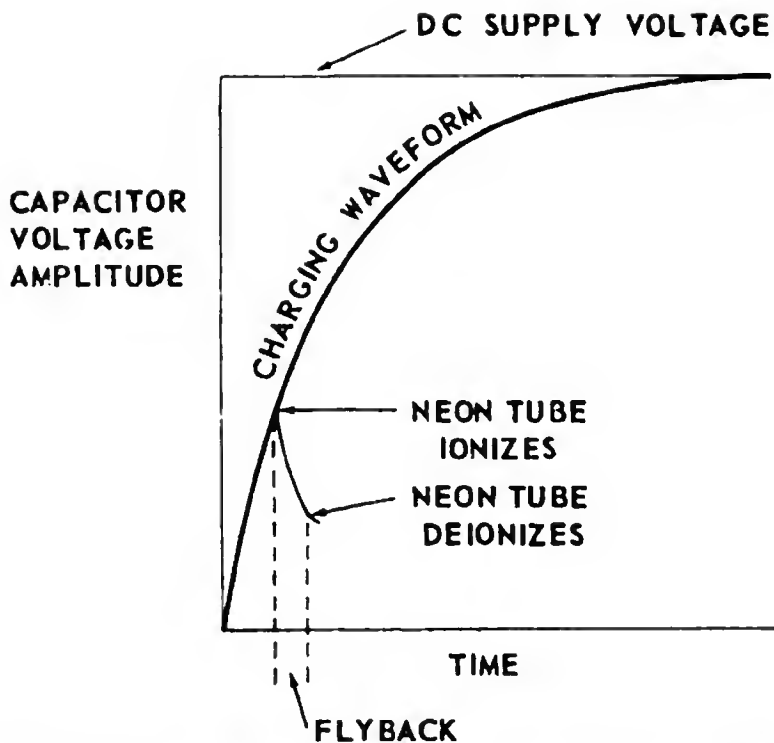


Figure 3-9.—Waveform of a capacitor charging through a resistor.

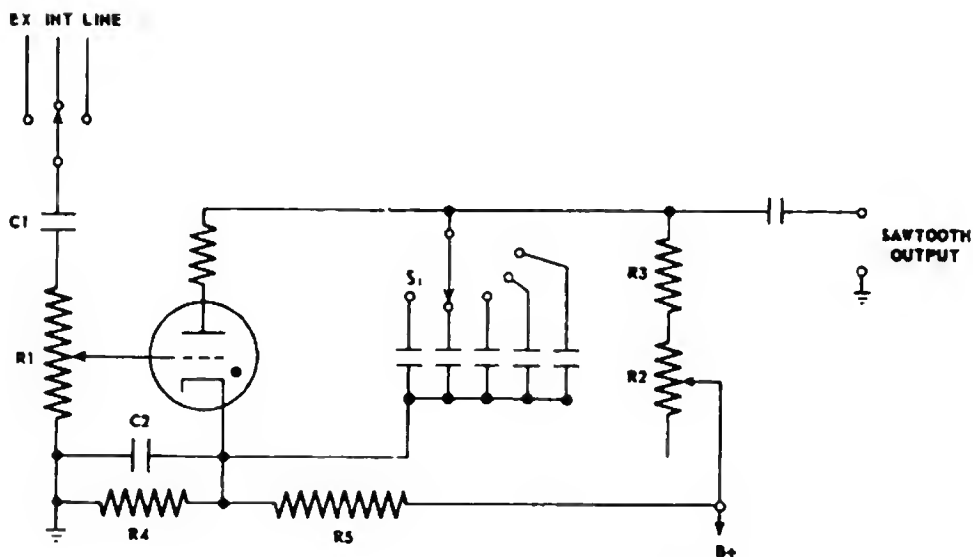


Figure 3-10.—Thyatron sweep generator.

grid of the thyratron when an external synchronizing signal is used. Potentiometer R1 determines the amount of synchronizing voltage applied.

If the frequency of the sweep generator is slightly different from that of the signal, the pattern will drift slowly one way or the other across the screen. To stabilize the pattern, the frequency of the sweep generator is made equal to (or a submultiple of) the signal frequency. The sweep frequency is then controlled automatically by applying a portion of the signal voltage to the thyratron grid in a manner that makes the tube fire at a particular voltage. The synchronizing process relies on the influence which the grid exerts on the ionization of the tube. The frequency of the sweep generator varies with the ionization potential of the tube. The higher the potential, the lower the frequency, if the R-C time constant is not changed.

The relation between the sweep generator voltage and a signal voltage of sine waveform shown in figure 3-11 represents a condition in which the two frequencies are not quite the same. The sync signal lowers the thyratron grid bias and ionizes (fires) the tube. The sweep frequency is made equal to the signal frequency by injecting a portion of the signal frequency as a sync signal in series with the grid bias supply. When the signal voltage has a positive peak, the sync voltage also has a positive peak and the tube ionizes. This makes the period of the pattern and the period of the sweep equal. Thus, the signal pattern appears stationary on the screen. This is called SYNCHRONIZATION.

When an oscilloscope is to be adjusted, first turn the synchronizing control to zero. Next, adjust the fine frequency control for maximum stability of the screen pattern. If the pattern still drifts on the screen, increase the sync voltage until a stable pattern is obtained. Distortion results if too much sync voltage is used.

In the electrostatic cathode-ray tube, positioning of the pattern on the screen is accomplished by adjusting the d-c potentials on the horizontal and vertical deflection plates. In figure 3-6 the d-c potentials are adjusted with two potentiometers in a bridge circuit. Moving the tap on each potentiometer varies the potential applied to the deflection plates from negative to positive values through the zero reference established by grounding the midpoint of the bridge. With the position controls the pattern can be moved so that any portion can be seen on the most desirable part of the screen.

**HORIZONTAL AMPLIFIER.**—The horizontal amplifier in the cathode-ray oscilloscope increases the amplitude of the saw-tooth voltage from the sweep generator before

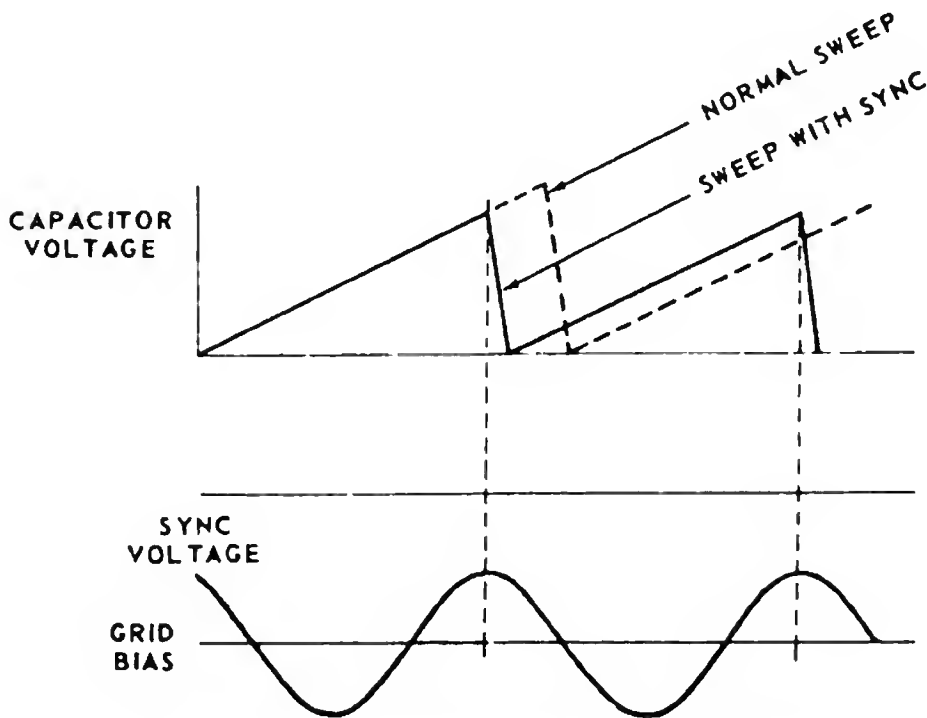


Figure 3-11.—Synchronization of a sweep voltage.

the saw-tooth voltage is applied to the horizontal deflection plates. The horizontal amplifier must handle a wide range of frequencies to keep the sweep linear.



wave rectifier with R-C filter (shown in the upper portion of figure 3-12) is sufficient to provide the high voltage to the first and second anodes and to the aquadag coating.

The full-wave rectifier (lower portion of figure 3-12) supplies the relatively low d-c plate and screen potentials for the amplifier tubes. When very stable operation is required, the output of the low voltage power supply is regulated. The power supply transformer secondary winding is arranged to furnish the high voltage d-c supply in series addition with half of the low voltage supply secondary.

Notice that the high voltage power supply is inverted—that is, the positive side is grounded. The second anode is therefore at ground potential although at a very high positive potential with respect to the control grid and cathode, which are negative with respect to ground. Operating the power supply in this manner prevents a strong field from being built up in the tube between the second anode and the deflection plates, which are operated at comparatively low potentials with respect to ground. It also makes possible the grounding of the aquadag coating for shielding purposes.

If two of the four deflection plates and the center of the positioning control bridge circuit are grounded, the small difference in potential between the grounded second anode and the deflection plates is not sufficient to defocus the beam. Grounding these points also prevents high voltage from appearing across the direct connected input terminals to the plates and eliminates the need for high voltage insulation of the positioning control.

### **OBL-3 Oscilloscope**

The essential circuits common to most cathode-ray oscilloscopes have been reviewed in the preceding paragraphs. Now let us consider a particular type of Navy oscilloscope, the OBL-3, shown in figure 3-13.



Figure 3-13.—Model OBL-3 cathode-ray oscilloscope.

Some of the uses of the OBL-3 are—checking the performance of power supply filters, checking distortion in audio amplifiers, measuring modulation percentage, and comparing an unknown frequency with a known frequency. One advantage of the oscilloscope over other indication instruments is that the oscilloscope is not easily damaged. The different circuits described earlier in this chapter are used in the OBL-3. A schematic diagram of this equipment is shown in figure 3-14.

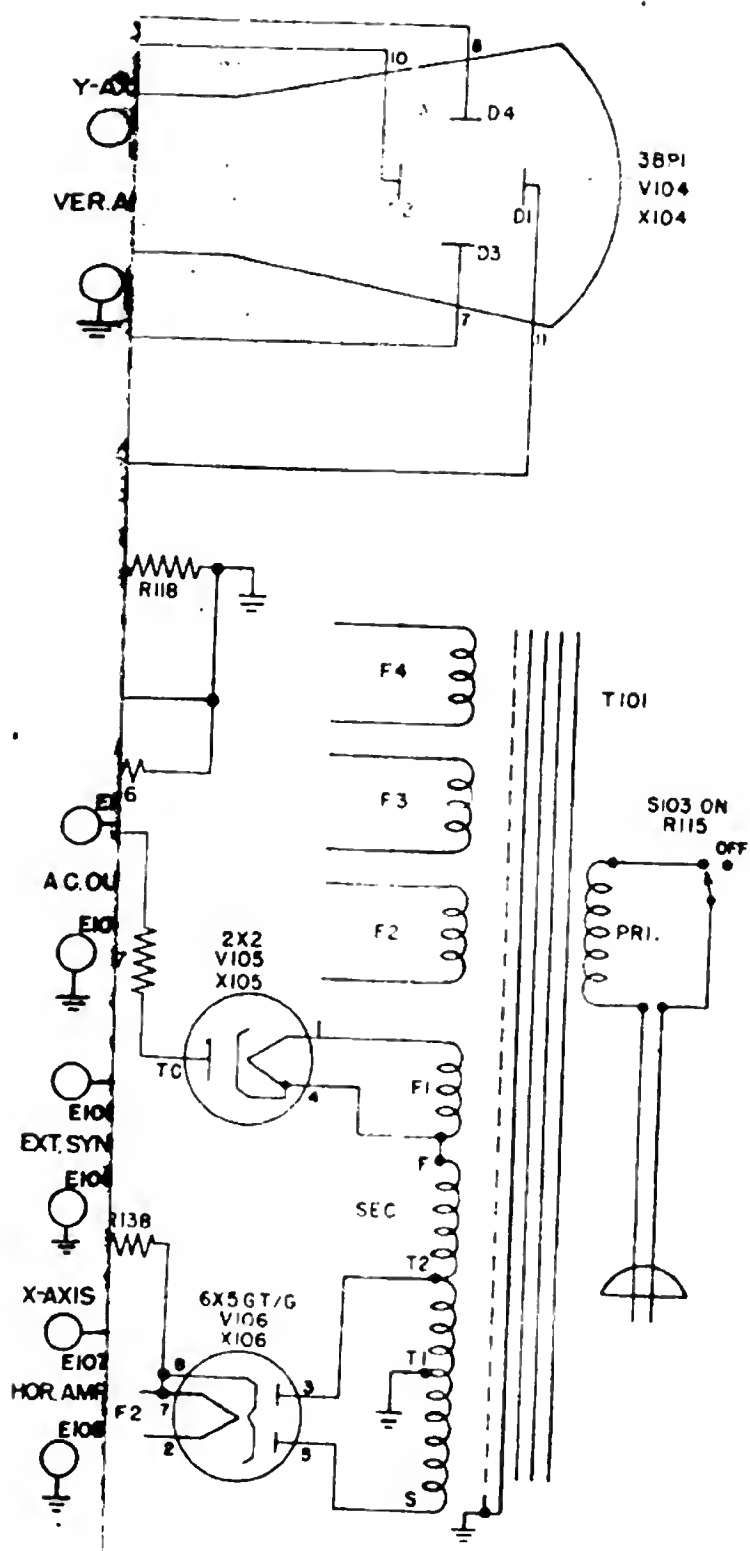
The sweep generator, vertical and horizontal amplifiers, synchronization, and power supply of the OBL-3 are essentially the same as those previously described. Only the features not described earlier are discussed here.

Signals applied to the vertical deflection plates may have a frequency of only a few cycles per second or many kilocycles per second. If it is desired to have only one cycle of the signal on the screen, the linear sweep must be able to cover the same frequencies as the signal input. Two controls affect the sweep frequency—switch S102, the sweep frequency control, and the sweep vernier potentiometer R126. They correspond to the coarse and fine frequency controls described earlier in this chapter.

Resistor R125 limits the maximum charging rate of the capacitor in the sweep generator. Resistors R121, R123, and R124 limit the peak current through the thyatron as the capacitors discharge. The saw-tooth voltage obtained from the sweep generator is coupled through switch S102 and capacitor C102 to the HOR GAIN control R102. R122 and C114 form a high frequency compensating network. The position of the horizontal gain control determines the amplitude of the sweep voltage placed on the horizontal deflection plates and, therefore, controls the length of the sweep line seen on the screen of the cathode-ray tube.

The locking control R120 determines the amount of sync voltage placed on the grid of the thyatron. Sync







switch S101 selects the source of synchronization. When the switch is in the INT position, the sync voltage is supplied from the input signal to the vertical deflection plates. When the switch is on EXT SYNC, an external sync voltage is fed to the sweep generator from terminals E105 and E106. In the OFF position, no sync voltage is fed to the sweep generator. In the LINE position, the sync is obtained from the 60-cycle supply.

In the OBL-3 the second anode is not grounded. Instead it is placed at a positive potential with respect to ground. A voltage divider made up of resistors R134, R133, R132, R129, R130, and R131 is placed across the low voltage power supply. The different voltages needed for the amplifiers, centering controls, sweep generator, and second anode of the CRT are obtained from this voltage divider. Bias for the thyratron, V103, is obtained from the voltage drop across R130 and R131. Resistor R131 is an internal adjustment for obtaining the proper amount of bias.

None of the deflection plates in this equipment are grounded. On the rear panel of the OBL-3 are pin jacks for connecting directly to the deflection plates. No connection can be made between the LO terminals of J101 and J102 and ground because this would short the beam control potential to ground. Similarly, the centering voltages would be shorted if either HI terminal were grounded.

## AUDIO OSCILLATORS

Audio oscillators may be used to check the performance of audio amplifiers or to modulate radio-frequency generators. There are two common types of audio oscillators used in the Navy.

One type is the beat-frequency audio oscillator. In this equipment two oscillators are used, one fixed and the other variable in frequency. The outputs of the oscillators are fed into a mixer. The difference frequency pro-

duced is the desired audio signal. This type of audio oscillator requires very careful shielding to prevent the two oscillators from locking-in at the low audio frequencies. Locking-in refers to the tendency of the two to operate on the same frequency, as the frequency of the variable oscillator approaches the frequency of the fixed oscillator.

The second type of audio oscillator is the resistance-capacity type. In this audio oscillator resistors and capacitors are used to determine the frequency directly. This type of equipment is described in this chapter.

### **LAJ-1 Audio Oscillator**

A typical audio oscillator used by electronics technicians is the LAJ-1. The range of this equipment is from 20 to 20,000 cycles per second. A block diagram of the LAJ-1 is shown in figure 3-15. The complete equipment consists of an oscillator, amplifier, attenuator, and power supply.

**OSCILLATOR SECTION.**—Figure 3-16 shows a simplified circuit of the oscillator section of the LAJ-1. The oscillator is basically a two-stage resistance coupled audio amplifier. Both negative and positive feedback are used in this circuit. A portion of the output of V102 is fed back to the cathode of V101 as negative feedback which increases the variation in current in the lamp in the cathode circuit to a greater extent than would exist without it. The effect of the unbypassed lamp resistance in the cathode circuit is that of negative feedback.

Part of the output of the second stage also is fed back to the grid of V101 as positive feedback. The negative feedback tends to keep the tube from oscillating. The phase and amplitude of the negative feedback voltage applied to the cathode of V101 remain constant.

However, when the positive feedback is in phase with the voltage on the grid and is equal to, or slightly greater than, the negative feedback, the stage will oscillate. The

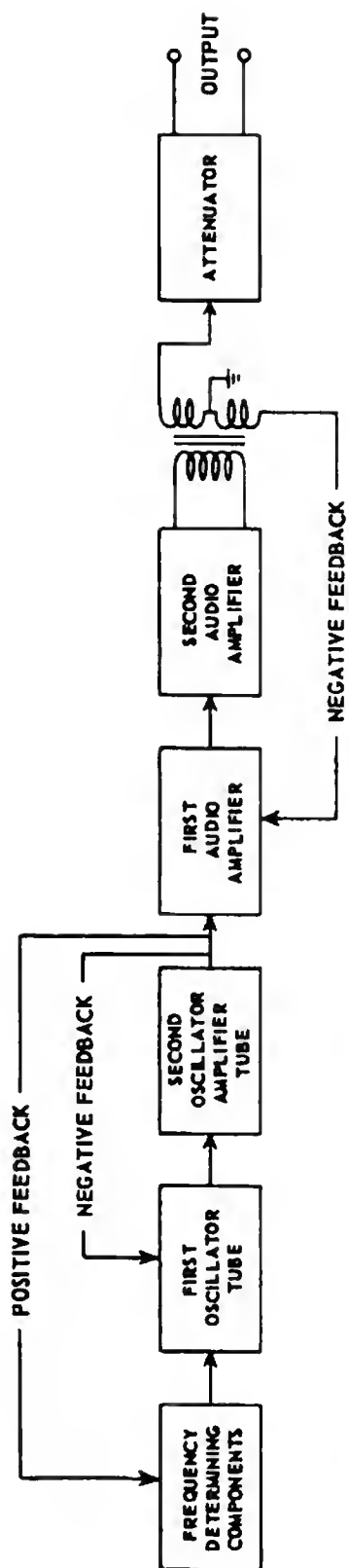


Figure 3-15.—Block diagram of the LAJ-1 audio oscillator.



The lamp bulb in the cathode of V101 acts as an automatic amplitude limiter. When the current flowing through the bulb increases, the resistance of the bulb increases and the negative feedback voltage increases. The increased negative feedback voltage lowers the amplification of the oscillator. If the current through the bulb decreases, the resistance of the bulb decreases, the nega-

tive feedback voltage decreases, and the output of the oscillator increases. In the LAJ-1 the capacity in the feedback circuit and that in the grid circuit are ganged on a common shaft. With this arrangement the capacitors track across the band of frequencies for which the equipment is designed. Different frequency ranges are obtained by switching in different resistors.

**AMPLIFIER SECTION.**—The amplifier section of the LAJ-1 is a conventional two-stage audio amplifier. A special winding on the output transformer is used to provide negative feedback to the first audio amplifier. The negative feedback reduces distortion in the amplifier. The power supply is a conventional fullwave power supply.

**ATTENUATOR.**—The output of the amplifier is fed to an attenuator. The attenuator is used as an amplitude control and keeps a constant load on the oscillator. The attenuator insures that the frequency will not change when the output amplitude is varied.

## R-F SIGNAL GENERATORS

The output from a secondary frequency-standard or frequency meter is too small to serve as a tracing signal for general servicing work. The r-f signal generator is less accurate than a frequency standard but nevertheless is adequate for servicing work. This generator is used in servicing radio receivers, radar receivers, and other types of equipment where an external source of r-f voltage is needed. Most signal generators have an r-f oscillator, a means of modulation, and an attenuator in the output. Many different types of signal generators are used in the Navy to cover the different frequency bands in which electronic equipment operates. In this chapter the model LP-5 radio frequency signal generator is described.

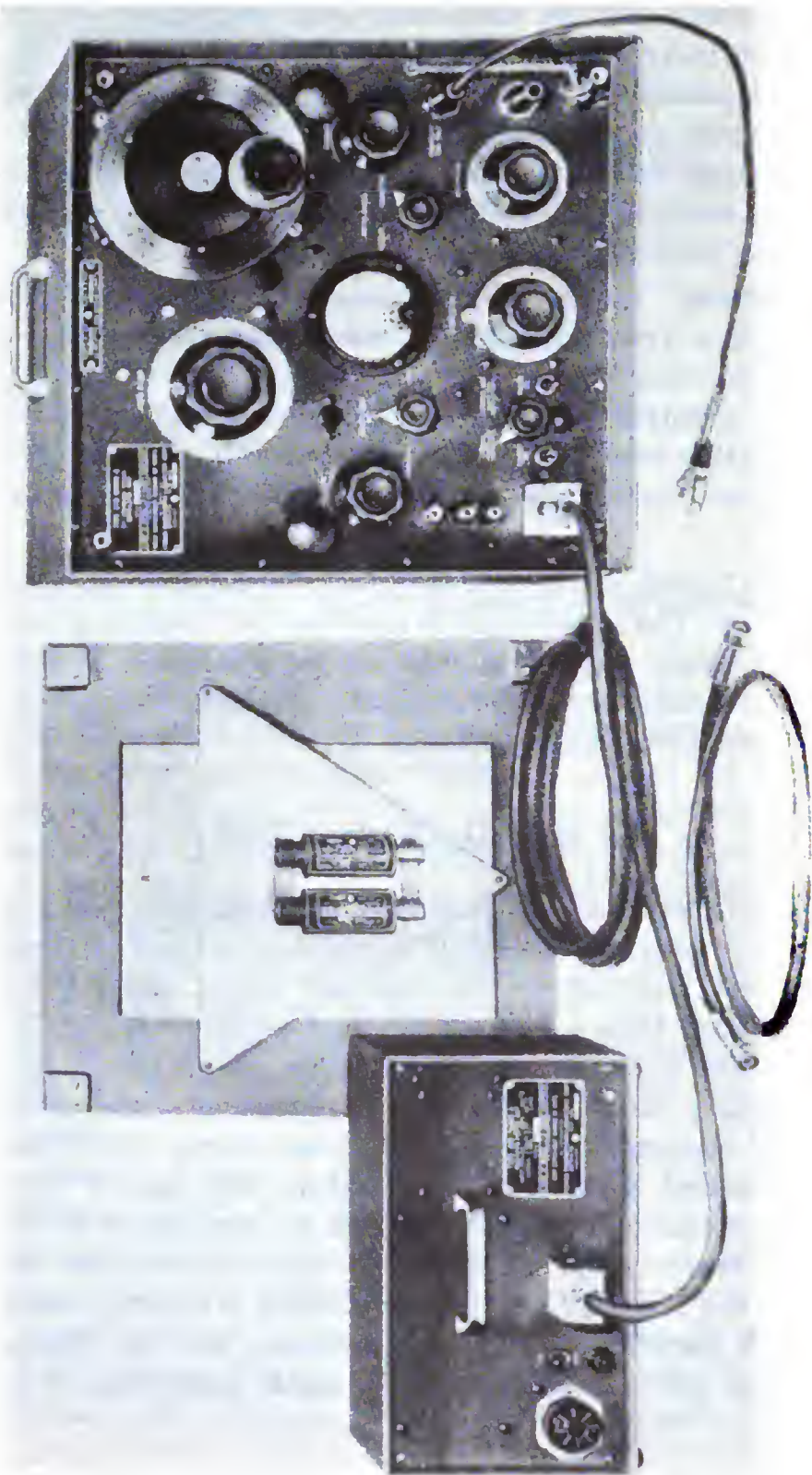


Figure 3-17.—LP-5 signal generator.



## Model LP-5

A pictorial diagram of the model LP-5 r-f signal generator is shown in figure 3-17. The model LP-5 has a frequency range between 9.5 and 50,000 kilocycles. The accuracy of the equipment is within  $\pm 1$  percent up to 30,000 kilocycles and within  $\pm 5$  percent above 30,000 kilocycles. The output voltage is variable between 0.5 microvolt and 0.1 volt. Also a fixed output of 1 volt is available.

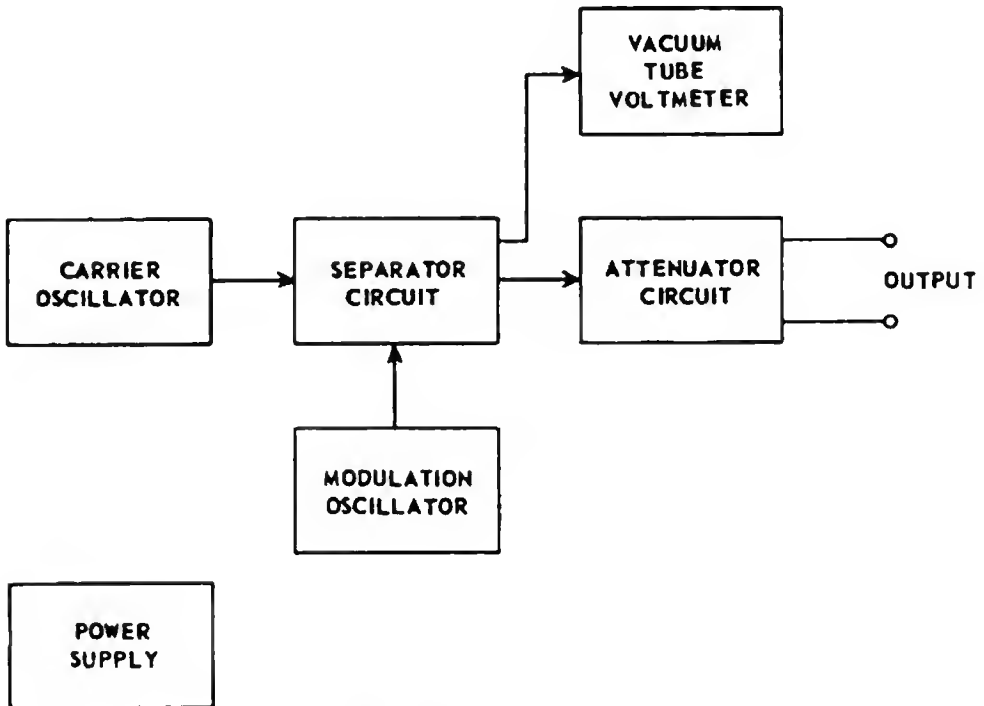


Figure 3-18.—Block diagram of the LP-5.

The LP-5 consists of a carrier oscillator, separator circuit, carrier vacuum-tube voltmeter, modulation oscillator, attenuator, and power supply. Figure 3-18 is a block diagram of the LP-5.

**CARRIER OSCILLATOR.**—A carrier oscillator generates the r-f voltage at the frequency determined by the tuning capacitor and the coil selected by the range switch.

The shape of the tuning capacitor rotor plates is especially designed so that the frequency scale is linear. A large value of tuning capacity is used in the oscillator. Because the tuning capacitor is large, the wiring and tube capacities make up only a small part of the total capacity. This makes realignment unnecessary when the oscillator tube is replaced. The r-f voltage output of the carrier oscillator may be varied by adjusting the carrier control. This control is a potentiometer which varies the plate voltage of the oscillator.

**SEPARATOR CIRCUIT.**—The separator is an amplifier be-

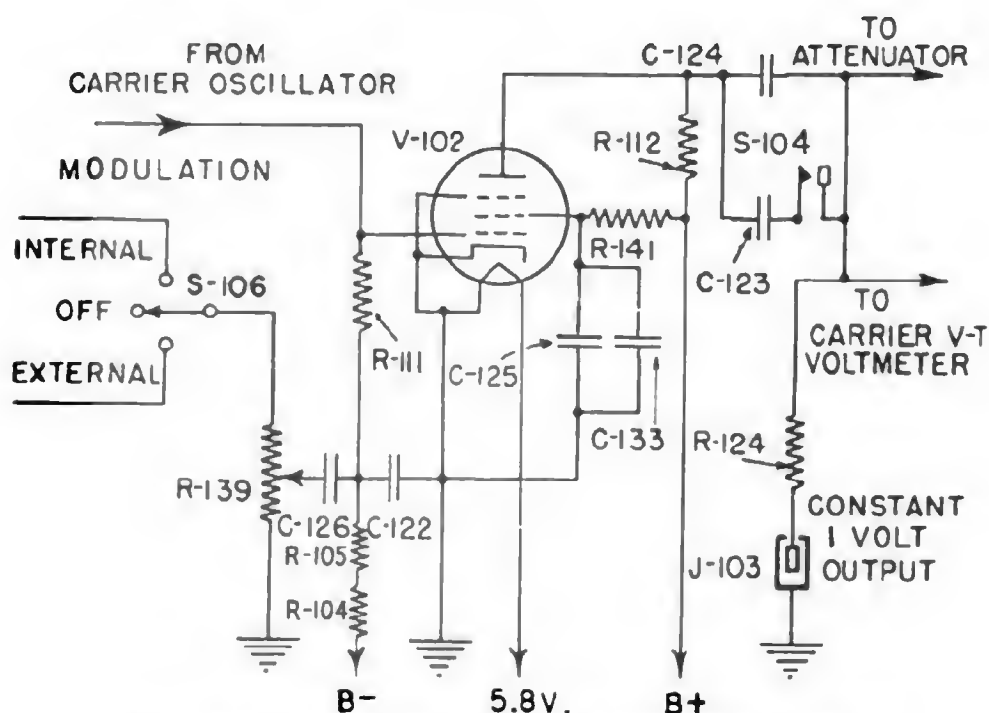


Figure 3-19.—Schematic diagram of the separator circuit.

tween the carrier oscillator and the attenuator. A schematic diagram of the separator circuit is shown in figure 3-19. The separator acts as a buffer stage and has two uses—(1) it stabilizes the carrier oscillator by isolating it from the attenuator, or load, and makes the oscillator frequency independent of both the setting of the attenu-

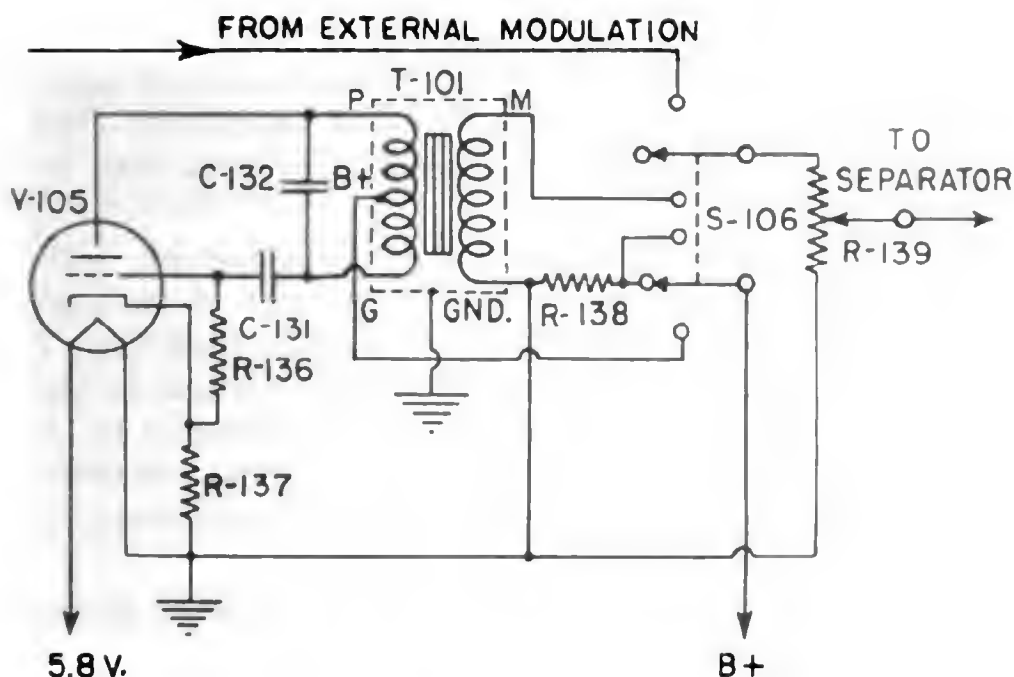


Figure 3-20.—Schematic diagram of the modulation oscillator.

ator controls and also of the load to which the generator is connected and (2) it provides a means of impressing modulation on the r-f signal. In figure 3-19 notice that the r-f signal and the modulating signal are impressed on the control grid of V102. The output of V102 is the r-f signal modulated with a 1000-cycle signal when switch S106 is in the INTERNAL position.

**MODULATION OSCILLATOR.**—A schematic of the modulation oscillator is shown in figure 3-20. The oscillator uses a modified Hartley circuit with an output of 1000 cycles. The output amplitude of the oscillator is varied by the modulation control R139. The modulation control determines the amount of modulation voltage applied to the separator tube. Any amount of modulation up to 50 per cent can be obtained by adjusting this control.

Modulation percentage is measured by the modulation vacuum-tube voltmeter on the front panel. When the modulation switch S106 is in the EXTERNAL or the OFF position, the plate voltage of the modulation oscillator is re-

moved. A dummy load, resistor R138, is placed in the circuit to keep a constant load on the power supply when the modulation oscillator tube is out of the circuit. This prevents a shift in frequency due to a reduced load on the power supply.

**VACUUM-TUBE VOLTMETER.**—The vacuum-tube voltmeter is used to measure either the percent of modulation placed on the r-f carrier or the amplitude of the r-f carrier. The position of the METER READS switch on the front panel determines which circuit the meter is in. A schematic diagram of the carrier vacuum-tube voltmeter and also of the modulation vacuum-tube voltmeter is shown in figure 3-21.

The carrier vacuum-tube voltmeter is connected across the input of the attenuator circuit. When a carrier signal of 1 volt is placed across the attenuator, the meter reads half-scale.

**ATTENUATOR AND MULTIPLIER.**—The attenuator and the multiplier are calibrated directly in microvolts. Because the attenuator is a ratio device, a means is needed to measure the input to the attenuator. The carrier control is used to adjust the output of the carrier oscillator until the required 1 volt is measured by the carrier vacuum-tube voltmeter. A type-995 acorn tube is used in the latter circuit. The low input capacity of this tube assures that the calibration is accurate over all the frequencies covered by the LP-5 signal generator.

Rheostat R129 provides the bias needed to adjust the steady component of plate current in V103 and balance the circuit. This control must be adjusted from time to time to compensate for changes in the characteristics of V103. Another rheostat R130 shunts the meter and is set to give half-scale deflection of the meter with 1 volt applied to the attenuator. Rheostat R130 is adjusted only when the voltmeter tube is replaced.

The modulation vacuum-tube voltmeter is used to meas-

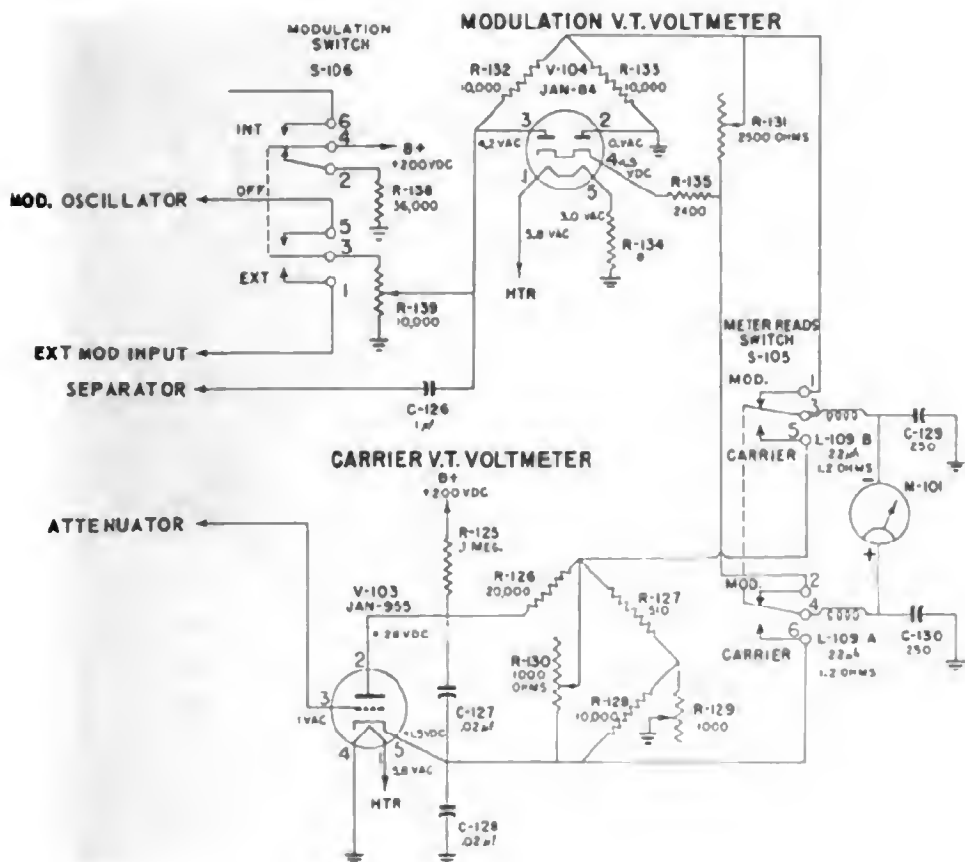
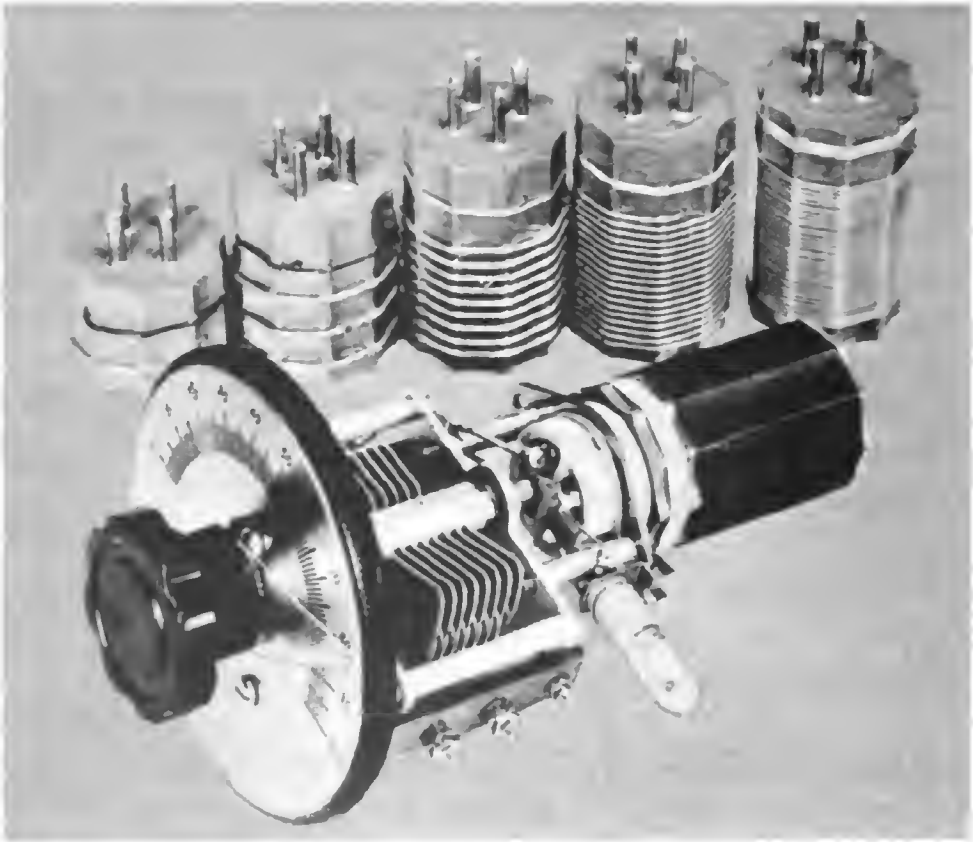


Figure 3-21.—Schematic diagram of the carrier and modulation vacuum-tube voltmeter circuits.

ure the amount of modulating voltage placed on the grid of the separator tube. The percentage of modulation is determined by the modulation potentiometer R139 shown in figure 3-19. A full-wave rectifier is used in the voltmeter circuit to prevent distortion of the modulation signal. The modulation voltmeter will measure either external or internal modulation depending on the position of the modulation selector switch. The same meter is used in the modulation voltmeter and the carrier voltmeter. The **METER-READS SWITCH** places the meter in the desired circuit.

The attenuator controls the amplitude of the signal connected to the output jack. The output voltage is continuously variable from zero to 100,000 microvolts. With a 1-



*Reprinted from the Radio Amateur's Handbook*

**Figure 3-22.—Pictorial diagram of an absorption wavemeter.**

volt signal across the input of the attenuator, the output voltage is read directly from the multiplier and microvolts scales. The lowest calibrated output voltage obtainable is 0.5 microvolt.

An output cable with a characteristic impedance of 90 ohms is supplied. At frequencies above 5 megacycles the cable begins to act as a transmission line. If the cable is not properly terminated, there will be serious errors in the output voltage.

A filter system is used to keep the r-f voltage out of the external modulation circuits and the cable connected to the power unit. This filter prevents undesired signals from being radiated and picked up by a receiver under test.

## FREQUENCY MEASUREMENT

### Absorption Wavemeter

Frequency can be measured with a resonant-tank circuit. The resonant circuit is made variable and has a calibrated dial. The indicating device usually is a lamp or meter. At high frequencies the resonant circuit may be lecher wires, coaxial stubs, butterfly circuits, or tuned cavities. Frequency meters of this type are known as **ABSORPTION WAVEMETERS**.

The absorption wavemeter absorbs energy when brought near a source of r-f energy. Figure 3-22 shows an absorption wavemeter. Resonance is ordinarily indicated by maximum brilliance of the lamp bulb. When the wavemeter is used to measure the frequency of an r-f oscillator, the oscillator grid meter shows a dip as the wavemeter is tuned through resonance.

Wavemeters cannot be used for accurate frequency measurements because they tend to change the frequency of self-excited oscillators to which they are coupled. Wavemeters are not very sensitive instruments. They are often used in connection with more sensitive frequency measuring instruments to make certain that the fundamental, not a harmonic is being measured.

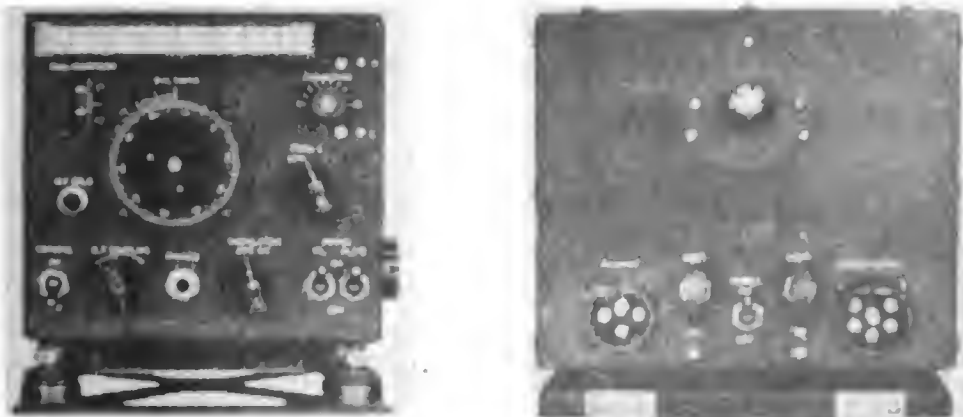


Figure 3-23.—Pictorial diagram of the LM-18 frequency meter.

For accurate frequency measurements, oscillating frequency standards are used. These instruments are similar to signal generators, but are more stable and accurate. However, they have a lower output than a signal generator. The frequency meter is used to measure frequency and to tune transmitters and receivers to the desired frequency. At frequent intervals a frequency meter must be compared to the primary frequency standard transmissions of radio station WWV or WWVH. This check insures that the comparison crystal in the frequency meter is still reliable.

### **LM-18 Heterodyne Frequency Meter**

A frequency meter used extensively on small craft, one of the LM series, is shown in figure 3-23. Several models of this meter have been built. These models are similar except for the power supply and some minor mechanical differences. The LM-18 frequency meter covers the band of frequencies from 125 to 20,000 kilocycles. This equipment has accuracies within 0.02 percent in the 125 to 2000 kilocycle band and within 0.01 percent in the 2000 to 20,000 kilocycle band.

Two oscillators are used in the LM-18—a crystal oscillator and a heterodyne oscillator. The crystal oscillator is used to calibrate the heterodyne oscillator at several different points over the entire band covered by the frequency meter. The LM-18 also contains a detector, audio amplifier, and modulator.

The fundamental frequency of the crystal oscillator is 1000 kilocycles. However, the oscillator output has a high harmonic content. A small capacitor is placed across the crystal so that, if the crystal frequency changes, an adjustment can be made to keep the crystal frequency close to 1000 kilocycles. Most of the frequency-determining components, including the crystal, are hermetically sealed to keep out moisture and dirt.



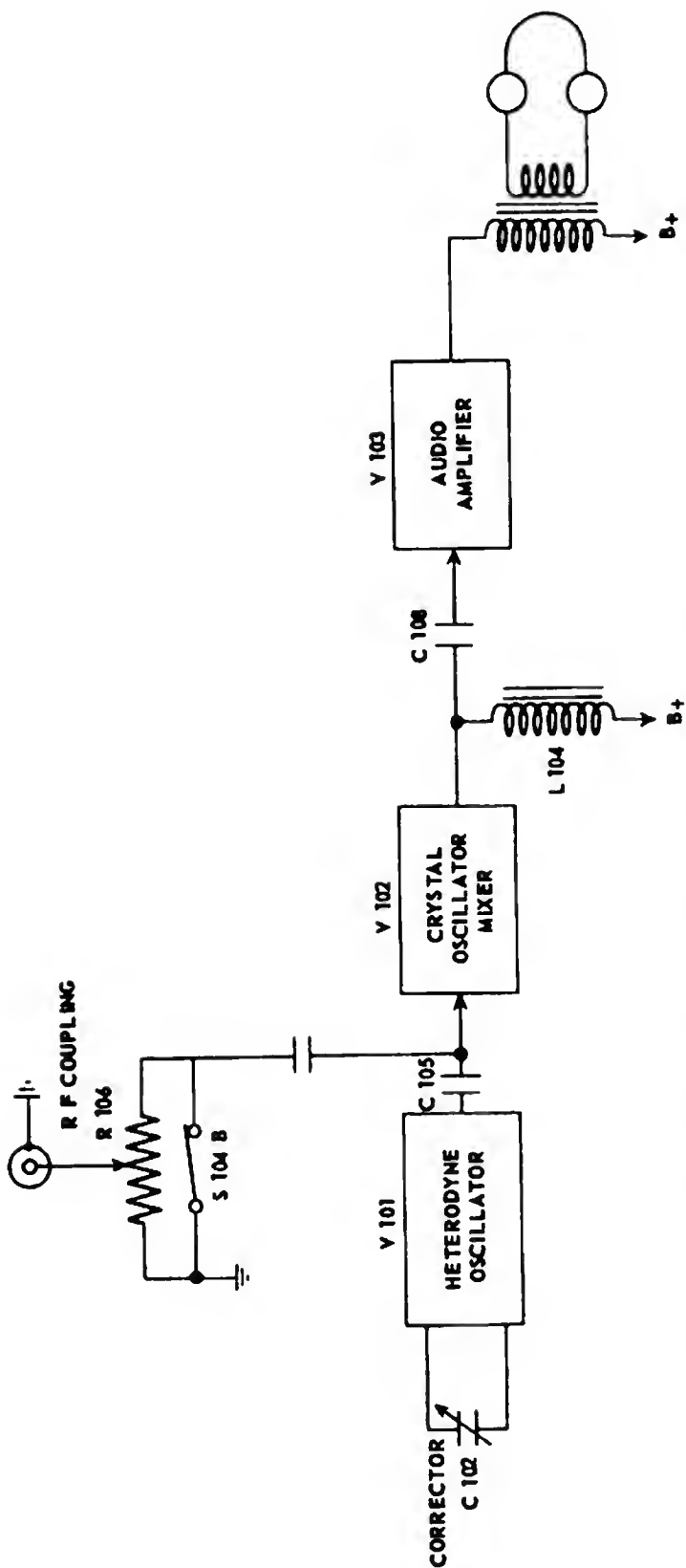


Figure 3-24.—Block diagram of LM-18 frequency meter when calibrating the heterodyne oscillator.

The band of frequencies measured by the LM-18 is covered in two ranges. The heterodyne oscillator has two continuously variable ranges that may be selected by the frequency band switch. In the LOW position a fundamental range of 125 to 250 kilocycles is used. By calibrating the first, second, fourth, and eighth harmonics of this range, continuous coverage from 125 to 2000 kilocycles is obtained. In the HIGH position of the switch the fundamental range of 2000 to 4000 kilocycles is calibrated over the first, second, fourth, and part of the fifth harmonic to provide continuous coverage through the range of 2000 to 20,000 kilocycles.

The LM-18 frequency meter can be used to tune transmitters and receivers (both c-w and m-c-w) and to measure the frequency of a received signal. Figure 3-24 shows a block diagram of the frequency meter when it is used

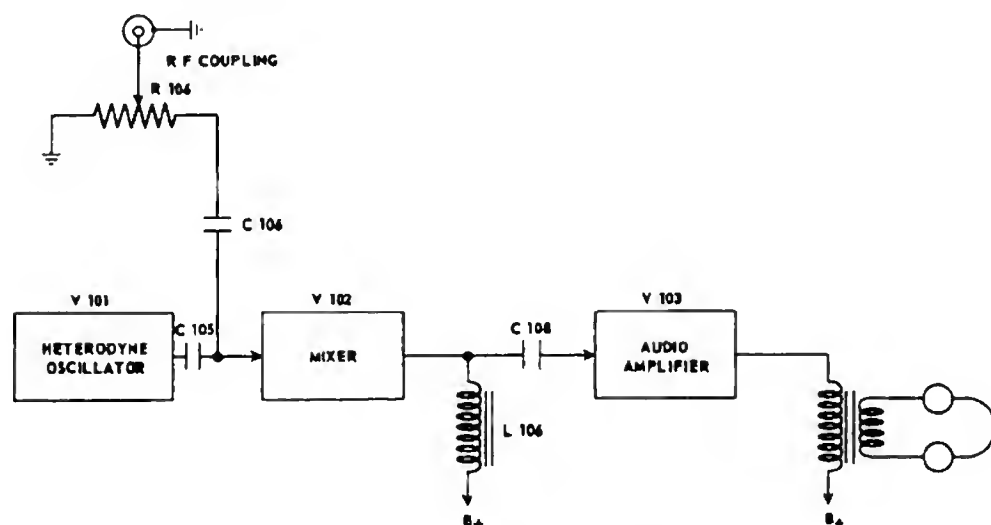


Figure 3-25.—Block diagram of the LM-18 frequency meter when tuning a transmitter or a receiver.

to compare the heterodyne oscillator with the crystal oscillator.

The output of the heterodyne oscillator is coupled to the grid of V102. Tube V102 is used as a crystal oscilla-

tor and mixer. The two oscillator frequencies beat together and the difference frequency is developed across choke L104. An audio amplifier, V103, amplifies the beat note and supplies it to a set of headphones. If a beat note is heard, the corrector C102 is adjusted until a zero beat is obtained. The heterodyne oscillator is connected to the crystal checkpoint nearest the frequency to be measured as shown in the calibration book. During the calibration procedure, r-f coupling control R106 is grounded by a section of S104 to prevent interference from external r-f signals.

Figure 3-25 is a block diagram of the LM-18 frequency meter when it is used to tune a receiver or a transmitter to a given frequency. The modulation and crystal switches

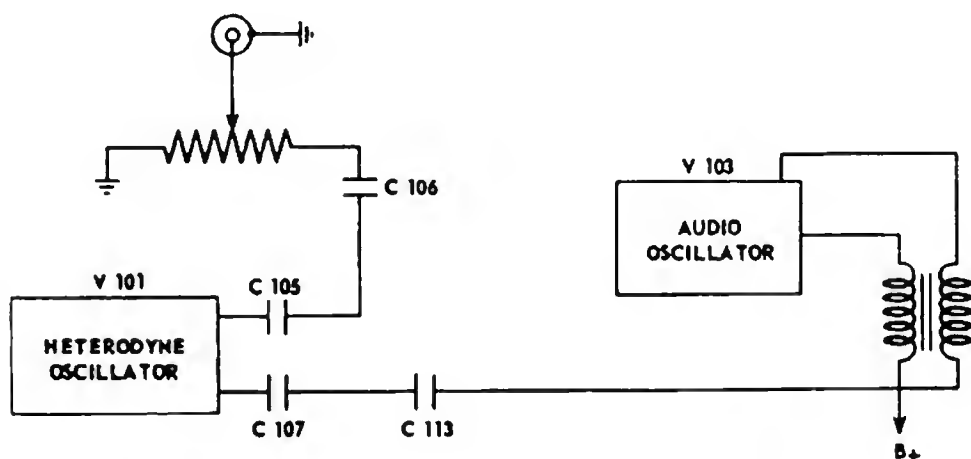


Figure 3-26.—Tuning an m-c-w receiver with the LM-18 frequency meter.

are in the OFF position for this operation. When tuning a receiver the heterodyne oscillator output is coupled through capacitors C105, C106, and potentiometer R106 to the receiver. The beat-frequency oscillator of the receiver is turned on and the receiver is tuned until a zero beat is heard in the output of the receiver.

When a transmitter is tuned, a portion of the transmitter oscillator signal is coupled into the frequency

meter through R106 and C106 to the mixer tube V102. This signal from the transmitter is mixed with the output of the heterodyne oscillator. The difference frequency is developed across L104 and amplified by V103. The output of V103 may be fed to a phone jack on the front of the transmitter for convenience because the transmitter usually is located at a distance from the frequency meter. A zero beat is heard when the transmitter frequency is the same as the frequency of the heterodyne oscillator.

Figure 3-26 shows a block diagram of the LM-18 frequency meter when it is used to tune an m-c-w receiver. The modulation switch is ON and the crystal switch is OFF. In this arrangement, the crystal oscillator-mixer is not used in the circuit. When the modulation switch is ON, the audio amplifier V103 becomes a 500-cycle audio oscillator. The output of the audio oscillator is fed to the suppressor grid of the heterodyne oscillator where it modulates the r-f signals generated by this tube. The output is fed to the m-c-w receiver. No zero beat is heard. Instead, the receiver is tuned for maximum output of the 500-cycle modulating signal. The r-f coupling control R106 is adjusted for the amount of frequency meter output signal needed.

The power supply is a separate unit. This unit supplies the a-c needed for the tube filaments and a high d-c plate voltage. The plate voltage is regulated so that the output frequency is stable regardless of variations of the line voltage to the power supply.

## SIGNAL STRENGTH MEASUREMENTS

The field-intensity meter is basically a portable radio receiver with a meter attached to indicate the strength of a received signal. A field-intensity meter is useful (1) for locating sources of radiated signals that violate radio



**Figure 3-27.—Pictorial diagram of OF-2 interference locating equipment.**

silence, (2) for locating the source of signals which interfere with radio receiving equipment, (3) for checking the effectiveness of measures for eliminating interference, and (4) for adjusting directional antenna arrays.

The field-intensity meter is tuned to the frequency of the interfering signal. Earphones are used to identify the signal. The meter indicates the strength of the signal received. To locate interference aboard ship, it is usually necessary to inspect all rotating machinery on the ship. A good check is to start and stop the machine suspected of causing the interference to see whether the signal disappears. Occasionally radar equipment can cause interference in lower frequency bands. Electric razors and automatic ignition systems cause difficulties in radio reception. Also the interference generated by such devices might be picked up by a sensitive direction finder on an enemy plane or submarine and thereby reveal the position of the ship.

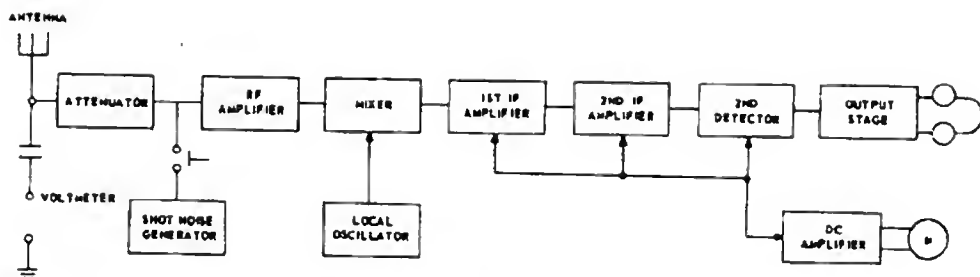


Figure 3-28.—Block diagram of the OF-2 interference locating equipment.

### Model OF-2 Interference Locating Equipment

The model OF-2 radio interference locator and field strength meter is designed to measure small radio-frequency voltages. A pictorial diagram of the OF-2 is shown in figure 3-27. This equipment may be used as a voltmeter to measure the strength of the signal emitted from a radio transmitter or rotating machine.

The OF-2 can be used to measure signals from 2.5 to 100,000 microvolts. All the scales except the range from 2.5 to 25 microvolts can be read directly. The full-scale reading of the OF-2 is 1000 microvolts. However, a radio frequency attenuator is provided in the input circuit to extend the full-scale range to 10,000 microvolts or to 100,000 microvolts.

A collapsible whip antenna with an effective electrical length of one meter is used with the OF-2. When the antenna is fully extended and the meter calibrated, the reading is in microvolts per meter.

The OF-2 is a conventional superheterodyne receiver with the addition of a noise generator and meter circuits. A block diagram of the OF-2 field-intensity meter is shown in figure 3-28. The shot-noise generator is employed for calibration purposes. The output of the noise generator is known. The unknown signal is measured by comparison with the noise signal. The gain of the first and second i-f amplifiers is controlled by a-v-c voltage. Two diodes are used in the second detector. One of the

diodes is used to obtain an audio signal that is amplified and made to drive a set of headphones. The other diode rectifies part of the signal and supplies a-v-c voltage. The a-v-c voltage is supplied to a d-c amplifier with a meter in the plate circuit.

A meter on the front panel measures the rectified a-v-c voltage. Because the a-v-c voltage is proportional to the input signal, the meter indirectly measures signal strength.

The necessary voltages used in the OF-2 are supplied entirely by batteries. No rectifiers or power transformers are needed. By means of the selector switch on the front panel the plate voltage and filament voltage can be measured.

257382 O-53---8

## QUIZ

1. What is the chief use of the cathode-ray tube?
2. What elements make up the electron gun of a cathode-ray tube?
3. How is a pattern produced on the screen of an electrostatic cathode-ray tube?
4. What is the deflection sensitivity of a cathode-ray tube?
5. What is the main purpose of the aquadag coating on the inside of the glass envelope of a cathode-ray tube?
6. What are the disadvantages of the neon bulb sweep generator?
7. Name two types of audio oscillators used in signal generators.
8. In figure 3-16 what is the purpose of the lamp in the cathode circuit of V101?
9. What characteristics distinguish an oscillating frequency meter from a signal generator?
10. Which of the two oscillators in the LM-18 frequency meter possesses the greater degree of stability?
11. Why is a frequency meter compared frequently with a primary frequency standard?
12. What are the essential components of a field-intensity meter?
13. What are some of the uses of a field-intensity meter?
14. What is the range of r-f voltage measurement of the model OF-2 interference locating equipment?



# CHAPTER

# 4

## LOW- AND MEDIUM-FREQUENCY RADIO TRANSMITTERS

### OPERATIONAL USES

Several factors must be considered when a certain frequency is to be selected for use during an operation. The Electronics Technician does not have anything to say about the choice of frequencies but a knowledge of some of the factors that determine their choice is desirable.

The very-low-frequency band from 10 to 30 kilocycles is not covered by shipboard transmitters. The antenna needed for such a low frequency could not be erected aboard a ship. However, there are some v-l-f stations on shore. One of the frequencies of the Primary Fleet Broadcast, NSS, is in the very-low-frequency band. Powerful v-l-f stations with their huge antennas are capable of transmitting signals through magnetic storms that blank out the higher radio frequency channels.

The low-frequency band from 30 to 300 kc is used mostly for long-range direction finding. This band provides a means of reliable medium and long range communication. It is possible to produce useful amounts of radiation in this band with antennas aboard ship. The frequencies in the low frequency band do not depend on sky waves and provide stable communications with little variation from season to season.

The area covered by the medium frequency band, from

300 to 3,000 kc, depends on the ground wave. Sky-wave reception of medium frequency waves is also possible. At the upper end of this band the ionosphere has a great effect on the sky waves. Relatively large distances can be obtained by using this band, if the correct frequency is used at the correct time. The international distress frequency, 500 kilocycles, is located in this band. Commercial broadcast stations as well as Navy stations operate in this band.

Another band used by the Navy is the high frequency band. This band contains the frequencies between 3 and 30 megacycles. The sky wave is increasingly important in this band, if long range communication is to be obtained. Propagation characteristics of waves in the high frequency band change with the time of day and the season. The choice of frequency depends on many variables in the ionosphere. For long range ship-to-ship and ship-to-shore communications either the high-frequency band or the upper part of the medium-frequency band is selected depending mostly on the time of day. Transmitters such as the TBM, TBL, TBK, and TDE cover part of the medium-frequency and most of the high-frequency bands. The TBL and TDE also cover a portion of the low-frequency band.

A few of the more important features that must be incorporated in every Navy transmitter are excellent frequency stability, ruggedness, long life, flexibility of operation, standard remote control operation, ease of tuning, and efficiency. Individual transmitters often have several modifications. The main differences in corresponding models are usually found in the power supplies or in some minor mechanical or electrical changes. Navy equipment is somewhat different from corresponding commercial equipment. Some of the differences may seem of little significance, but over a period of years the equipment designed for naval use has proved superior.

# MODULATION IN NAVY L-F AND M-F TRANSMITTERS

## Types of Modulation

The simplest way of sending messages with a radio transmitter is by interrupting the carrier with a key to form dots and dashes. A system that uses a code with dots, dashes, or a combination of both to form letters is called CONTINUOUS-WAVE (c-w) TRANSMISSION. This was the first type of modulation ever used and it still is used quite extensively today. Some of the advantages of c-w transmission are narrow bandwidth, high intelligibility even under severe noise conditions, and security since the message may be encrypted.

Several methods of automatic c-w transmission have been developed. Automatic transmission can be obtained by having a punched or inked tape key the transmitter. The automatic keying of transmitters with tapes is desirable where large volumes of transmissions are handled such as at a communications center. On the receiving end, when brief high-speed transmissions are received, the output of the receiver can be used to ink or punch another tape which may be transcribed later at a slower speed.

Although automatic transmission has the advantage of speed, most radiotelegraph messages are sent by a hand key at relatively slow speeds. These messages are received aurally by the operator and transcribed with a typewriter.

A system of automatic transmission and reception that is becoming increasingly important is teletype. The teletypewriter looks somewhat like a standard typewriter. A teletypewriter is used at the transmitting end and a similar machine at the receiving end. An advantage of this method is that at both the sending and receiving stations a permanent record of the message is made. Greater

speeds are obtained with unskilled radio operators because only a knowledge of typewriting is needed.

Modulated-continuous-wave transmission (m-c-w), a system similar to c-w, makes use of an audio signal of about 800 cycles per second impressed on the carrier. M-c-w is used with low frequency transmitters because most low-frequency receivers are not equipped with a beat frequency oscillator. This system of modulation is not used very extensively today. A modified m-c-w system is used for the transmission of certain types of radio teletype signals.

The type of modulation familiar to most people is amplitude modulation (a-m). Where rapid communication is needed, but no permanent record is required, voice transmissions are used. The intelligence in a-m systems is impressed on the r-f carrier by varying the amplitude of the carrier. Some of the uses of a-m are communication with shore fire control parties, maneuvering messages, and tactical messages. Voice transmissions are important because the operator does not have to be familiar with the telegraph code.

Long range communications are usually accomplished with c-w transmissions. Relatively short range communications, such as ship-to-ship and ship-to-shore communications, are obtained by voice transmissions.

## Teletype

Teletype replaces the operator for changing the plain language into code and the code into plain language. To transmit a message with teletype the operator presses keys on a keyboard similar to a standard typewriter. As each key is pressed, mechanical cams and linkages cause a sequence of mark and space signals to be sent out by the transmitter.

At the receiving end the received signal sequence actuates selector magnets in a similar machine that causes

the character transmitted to be printed on a paper and the carriage to be advanced one space. At the end of each line a special sequence of impulses causes the paper to be advanced one line.

In the teletype code each character consists of five impulses composed of MARKS and SPACES. Each group of five impulses is preceded by a start impulse and followed by a stop impulse to ensure synchronism between all the stations on a circuit. The sequence of impulses can be used to key a transmitter through suitable convertors. A photograph of a model-15 teletypewriter is shown in figure 4-1.



**Figure 4-1.—Model-15 teletypewriter.**

## **On-Off Keying**

The easiest way of transmitting teletype impulses is on-off keying. On-off keying consists of having a period of emission from the transmitter representing the "mark" condition and a period of no emission representing the "space" condition. This is somewhat similar to keying the transmitter by hand. The main advantage of on-off keying is that the equipment needed is readily available. However, it has several disadvantages. The most serious disadvantage is the fact that the automatic gain control of the receiver cannot be used to compensate for fading because the carrier is turned off and on.

## **Frequency Shift Keying**

The disadvantages of on-off keying are overcome by the use of frequency-shift keying (FSK). The main advantage of frequency-shift keying is its ability to provide a useful signal under severe fading and high noise levels. This results in greater stability and lower distortion than in the on-off system.

Frequency-shift keying is obtained by shifting the frequency of a transmitter above and below an imaginary "center frequency." One frequency corresponds to the "mark" condition and the other is the "space." The carrier shift is very small compared to the frequency of the carrier, usually 850 cycles total. Since this is true, excellent frequency stabilization is necessary at both the transmitter and the receiver if successful communication is to be achieved. This is the most serious disadvantage of FSK. The problem of frequency stability of the center frequency becomes increasingly magnified as the frequency is increased.

## **Two-tone Keying**

A scheme that dispenses with the need for excellent frequency stability is two-tone keying. Whereas FSK is

sensitive to frequency variations, amplitude-modulated circuits are relatively insensitive to minor frequency changes. Thus a slight mistuning of a receiver may result only in a reduction of signal strength. Two-tone keying is used in systems where many teletype machines operate on a single frequency.

In two-tone keying, a carrier is amplitude-modulated with two audio tones. Usually a 500-cycle tone is used for a space and a 700-cycle tone for a mark. Two-tone keying makes use of the advantages of both on-off and frequency-shift keying.

## FREQUENCY STABILITY

One of the major problems encountered with a transmitter is frequency drift. The frequency of a transmitter should be stable enough to avoid wandering into another band and to permit a receiver to stay on the transmitter frequency. However, the master oscillator in a transmitter tends to change frequency when it is being warmed up, when it suffers vibration or shocks, and when it is loaded heavily.

The frequency of a transmitter can be stabilized by the use of a crystal oscillator. However, this arrangement would require a large number of crystals to cover the many frequency channels used by the Navy. A more flexible means of obtaining stability is to control the frequency of a transmitter with a variable master oscillator.

Most of the frequency drift in a variable master oscillator is due to change in the size of the coils and capacitors and changes in the oscillator tube characteristics as they come up to operating temperature. Placing the frequency-determining components of the oscillator in a temperature-controlled oven eliminates this drift. To insure further stability the oscillator is loaded very lightly and isolated by a buffer stage.

The frequency of the master oscillator can be affected also by vibration and sudden shocks. In some transmitters all of the oscillator elements are mounted in a single oscillator unit. The oscillator unit is then suspended on springs and snubbed by sponge rubber cushions to keep the shock and vibrations reaching the oscillator unit at a minimum.

Frequency stability becomes important when a transmitter uses frequency multiplier stages because any drift in the oscillator frequency will be multiplied in these stages. For example, if the output frequency is eight times the oscillator frequency, any drift of the oscillator will be multiplied by eight.

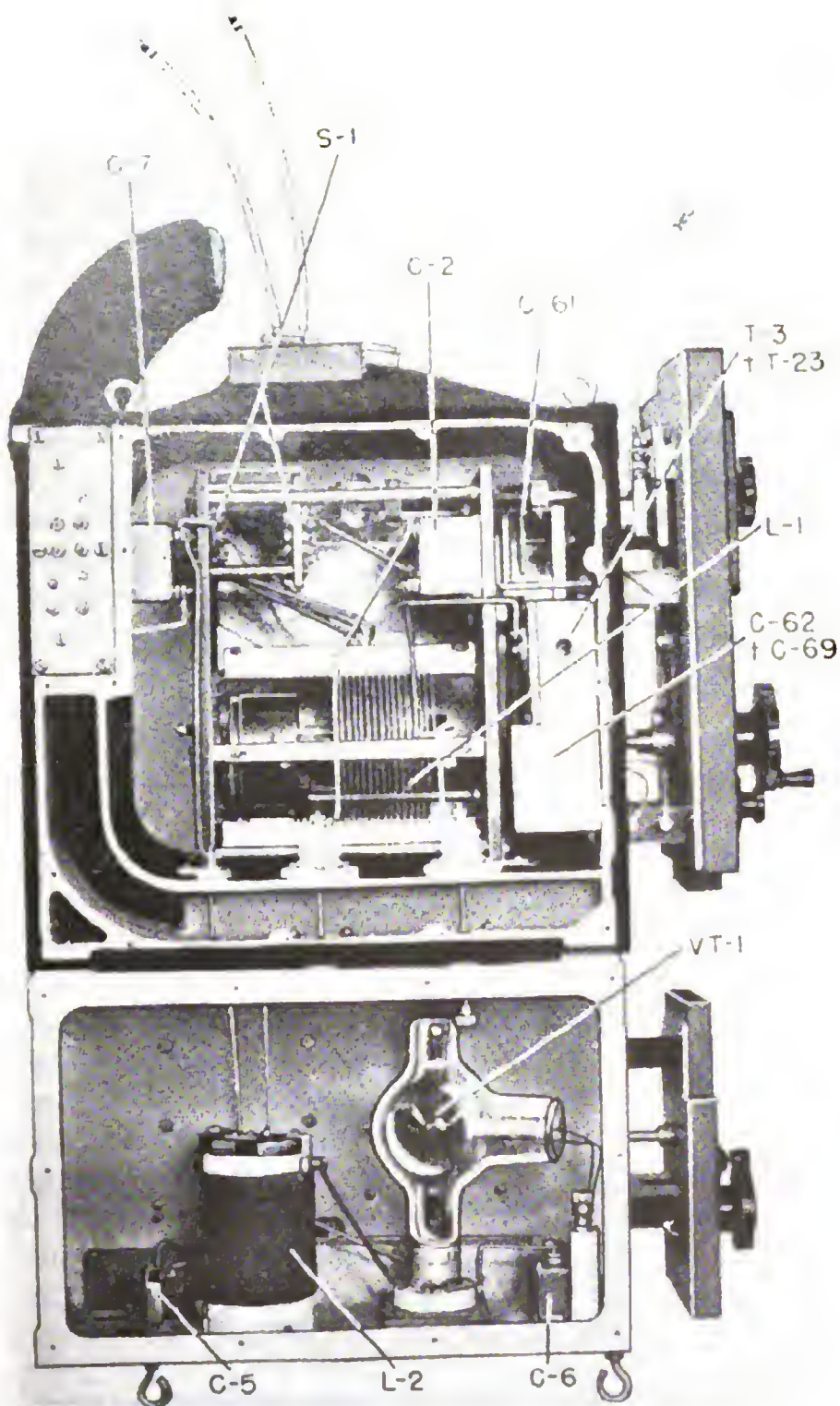
A typical means of insuring frequency stability is the temperature-control circuit of the master oscillator in the TBK transmitter. A photograph of the oscillator is shown in figure 4-2. All of the frequency-determining components except the master oscillator tube are mounted in a temperature-controlled oven. The circuit components including the wiring are rigidly mounted in the master oscillator unit. The complete unit is suspended in coil springs to prevent vibrations and sudden shocks from affecting the master oscillator.

### Temperature-Controlled Oven

Figure 4-3 is a schematic diagram of the temperature-control circuit. When the circuit is first energized, the temperature in the oven will be lower than the operating temperature of the oven. As long as the temperature is below 60.5°C, the mercury in thermostat S13 will be below two platinum wires which extend into the thermostat. In this condition resistor R50 will be in series with the thermostat relay K20A and the relay will not draw sufficient current to close.

With the thermostat relay deenergized the heating elements R26 draw current and heat the oven. When





† INDICATES PARTS FOR 25 CYCLE OPERATION

Figure 4-2.—TBK master oscillator.

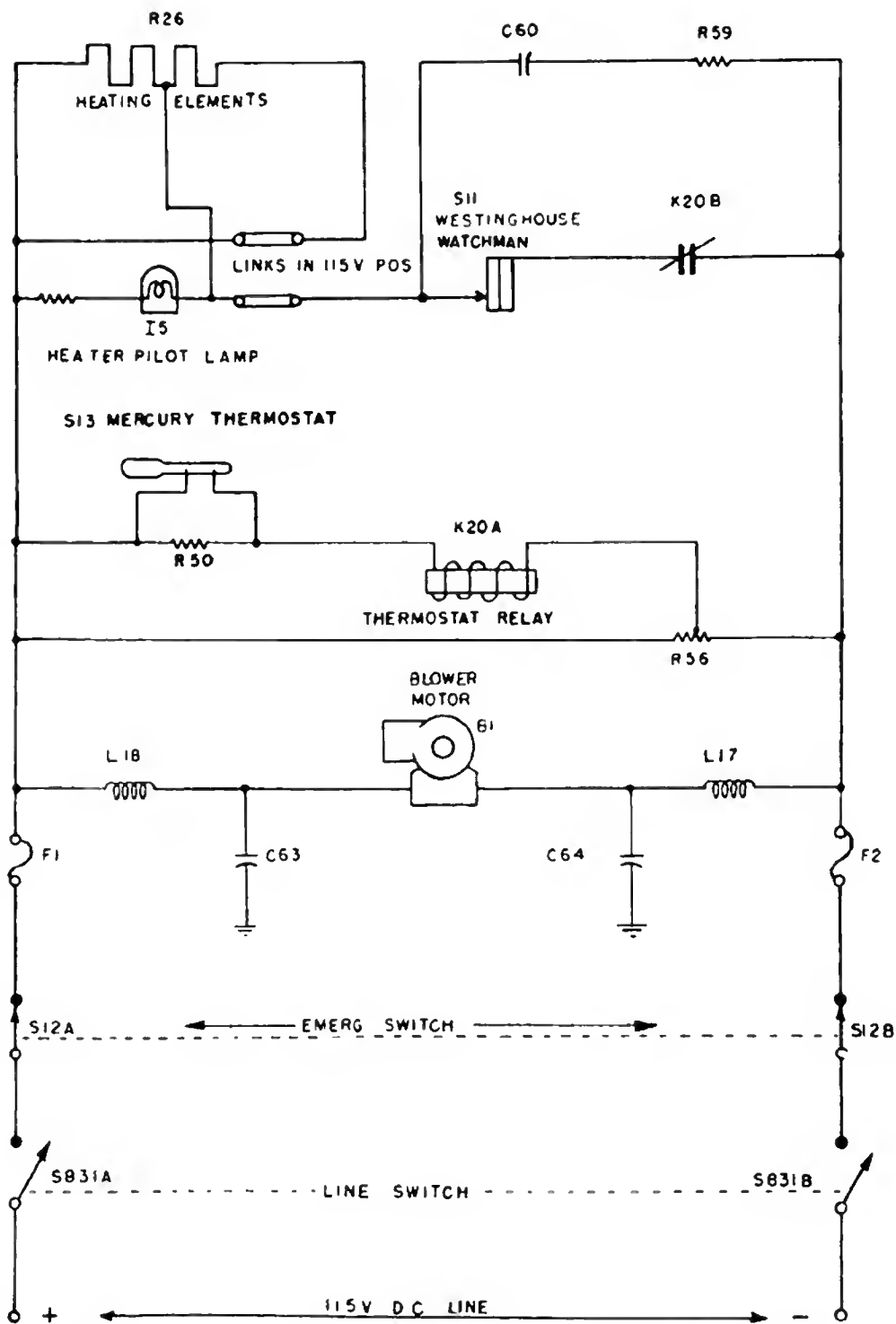


Figure 4-3.—Schematic diagram of the temperature-control circuit.

the mercury column in the thermostat rises enough to short out the contacts inside the thermostat, resistor R50 is bypassed and the thermostat relay is energized. This causes its contact K20B to open and deenergize the heating elements. When the temperature in the oven drops, the mercury column falls below the platinum contacts and allows the thermostat relay to open. When the thermostat relay opens, its contact K20B closes. This energizes the heating elements again and the cycle repeats.

A Westinghouse watchman S11, which is a thermostatic switch, is placed in the circuit to insure that the heat inside the oven will not become excessive in case the thermostat or thermostat relay fail to function. The blower motor circulates the air in the oven to keep all the components at an even temperature.

The circuit just described is somewhat elaborate. Not all Navy transmitters use all of these refinements but every transmitter has some means of insuring frequency stability.

### Master Oscillators

The majority of master oscillator circuits in low and medium frequency Navy transmitters are electron-coupled oscillators because of their stability.

The frequency of an oscillator is varied by either a variable capacitor or a variable inductance. Different frequency ranges are obtained by using a tapped oscillator coil or by switching in various values of capacity. Sometimes both methods are used together. Usually the frequency of the oscillator is doubled in the plate circuit. With this arrangement any energy fed back to the grid circuit is twice the frequency of the energy in the grid circuit and does not affect the stability of the oscillator.

A schematic diagram of the master oscillator used in the TBK transmitter is shown in figure 4-4. This oscillator is typical of the circuits used in most of the Navy's



low and medium frequency transmitters. An electron-coupled oscillator is used as the master oscillator. The range switch S1 selects different values of inductance and capacity for different ranges of the oscillator. The frequency is varied, within the range selected, by a copper slug that is moved in or out of inductor L1. When the tube and parts age or are replaced, small changes in capacity may occur.

The oscillator dial is calibrated directly in frequency and any change in the capacity will cause the calibration to be in error. Capacitor C61 is used to compensate for these small changes and to make the oscillator track with the dial readings. This is a screw-driver adjustment.

Capacitor C62 is a special device that changes capacity when the oscillator is keyed. It compensates for the change in the tube interelectrode capacity when the oscillator is keyed. This change is caused by the heating of the tube elements. One plate of the capacitor is a bimetallic strip heated by transformer T3 during the time the oscillator is keyed. The bending of the bimetallic strip changes the capacity of C62. This compensates for the change in interelectrode capacity. Capacitor C13 couples the oscillator output to the doubler tank. It is adjusted to provide sufficient coupling over the entire band covered by the transmitter.

The oscillator is keyed by grounding the center tap of the filament transformer through relay contacts K1C. The R-C combination of R4 and C45 is a click filter that reduces arcing across the keying contacts. Inductor L16 is a thump filter. The click and thump filters reduce interference in nearby receivers by modifying the beginning and the end of each keying waveform.

## TRANSMITTER CONTROL CIRCUITS

The transmitters installed aboard ships and on shore stations are normally controlled at a point some dis-

tance away from the transmitter room. If the transmitter is to be keyed and turned on or off at a remote position, some circuit is needed to perform these functions.

A control circuit of a transmitter is shown in figure

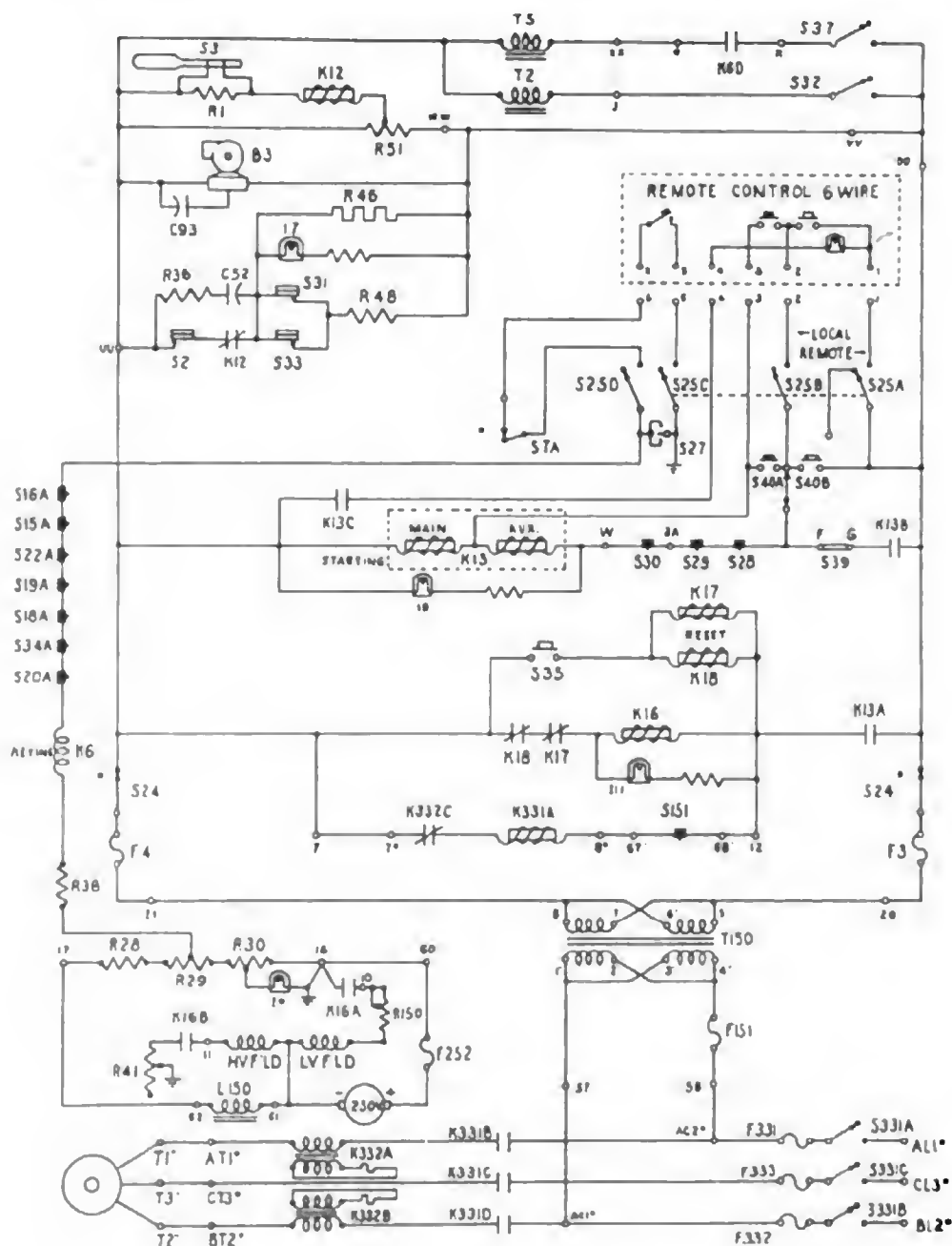


Figure 4-5.—TBL control circuit.

4-5. This is the standard six-wire control circuit used in the Navy. The control circuits in different transmitters may vary somewhat from the circuit shown, but basically they are the same. The temperature-control circuit shown at the top of the figure is similar to the circuit shown in figure 4-3. The remaining part of figure 4-5 is the transmitter control circuit and is discussed here.

Closing the main switch S331 applies power to transformer T150. Depressing the start button S40B energizes relay K13. When relay K13 is energized its contacts K13A, K13B, and K13C close. The closing of contact K13B holds the main starting relay across the line after the start button is released. The transmitter is turned off by pressing the stop button S40A. This button shorts out the auxiliary starting relay and allows relays K13 and K16 to open.

Power is supplied to the motor when contact K13A closes. This energizes relay K331A and causes contacts K331B, K331C, and K331D to close. Also, when contact K13A closes, relay K16 is energized. This closes its contacts K16A and K16B and supplies bias voltage to the transmitter and excitation voltage for the high voltage generator field. Lamp I4 is lighted when the bias voltage is present.

Relays K332A and K332B are thermal overload relays that protect the motor should it overheat. Either relay can open contact K332C, a manual reset contactor, which deenergizes K331A whose contacts disconnect the motor generator from the 3-phase line.

Two overloaded relays, not shown on the diagram K17 and K18, are located in the ground lead of the high voltage supply. Any overload will trip these relays and remove plate and grid voltage from the tubes. Reset coils K17 and K18 on the diagram are used to reset these overload relays.

When the LOCAL-REMOTE switch is in the REMOTE position, the local-start switch, stop switch, and keying terminals are paralleled by similar remote switches and contacts. There is no limit to the number of six-wire remote control units that can be used with a transmitter. Some remote control boxes have jacks for microphones but the C-W/M-C-W-PHONE switch on the front of the transmitter must be set locally. Switch S24 is an emergency stop switch to remove all power from the equipment.

## KEYING CIRCUITS

Most Navy transmitters have the hand telegraph key at a low potential. The keying bar is usually grounded to protect the operator. In most transmitters a keying relay with its contacts in the center tap of the filament transformer is used to key the equipment. Because one or more stages use the same filament transformer these stages are also keyed. The final amplifier, which is operated class-C with fixed bias, is usually not keyed. If no excitation is applied to the final amplifier tube, no space current flows through the tube, since the tube is biased beyond cutoff. For this reason, it is not practical to key the final amplifier. Click filters are installed in the keying lead to prevent interference with nearby receivers.

## TBL TRANSMITTER

The TBL transmitter consists of two entirely separate transmitter circuits to cover the frequency bands of 175 to 600 kc and 2000 to 18,100 kc. A photograph of the TBL is shown in figure 4-6. The two circuits use common vacuum tubes in all stages except in the master oscillator.

A block diagram of the TBL is shown in figure 4-7. The TBL has a normal output of 200 watts on c-w emis-



sion. An m-c-w output of 100 watts can be obtained from the i-f section only. Voice modulation circuits are not included as part of the TBL transmitter. If voice opera-

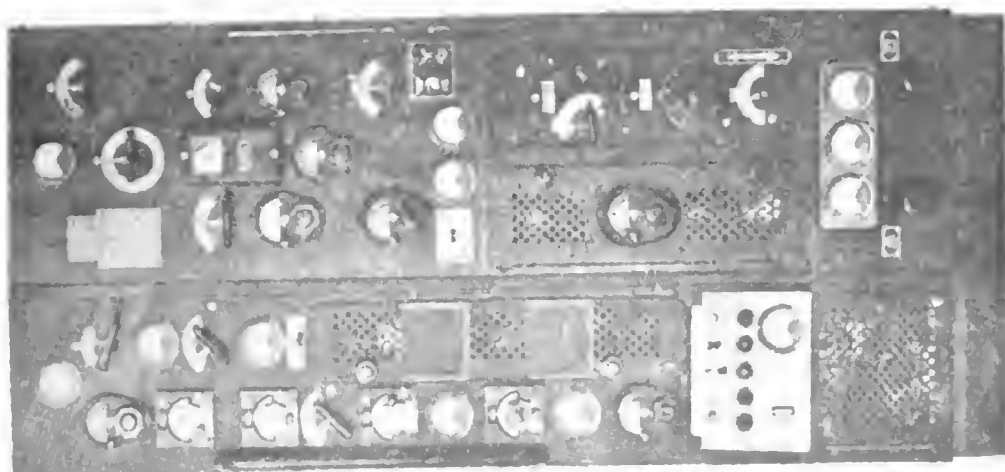


Figure 4-6.—TBL transmitter.

tion is desired, a separate modulation unit must be installed with the transmitter. When the modulation unit is used, the final amplifier of the transmitter is suppressor-grid modulated. The power output of the transmitter is 50 watts for voice operation.

The frequency-determining components of both the i-f

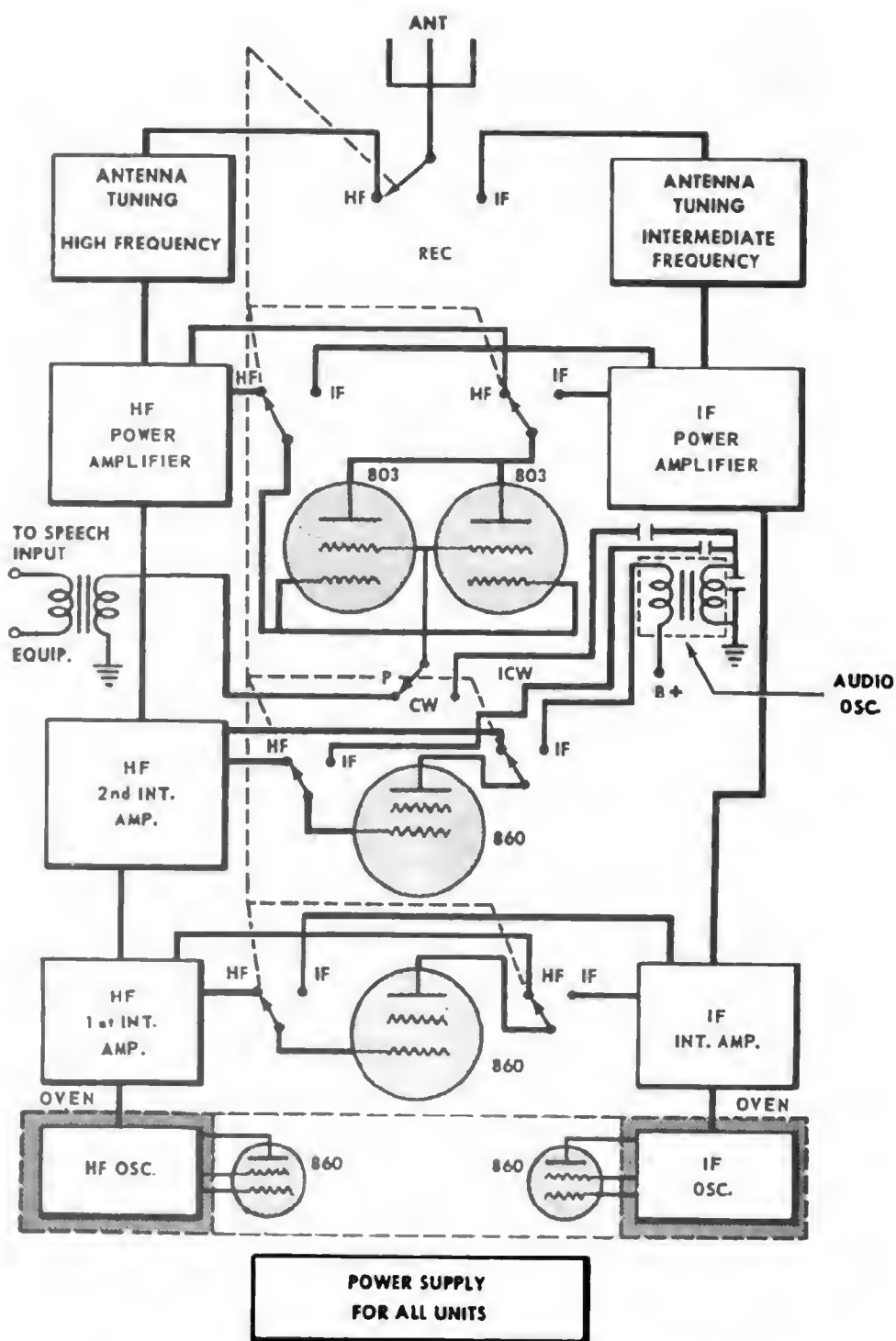
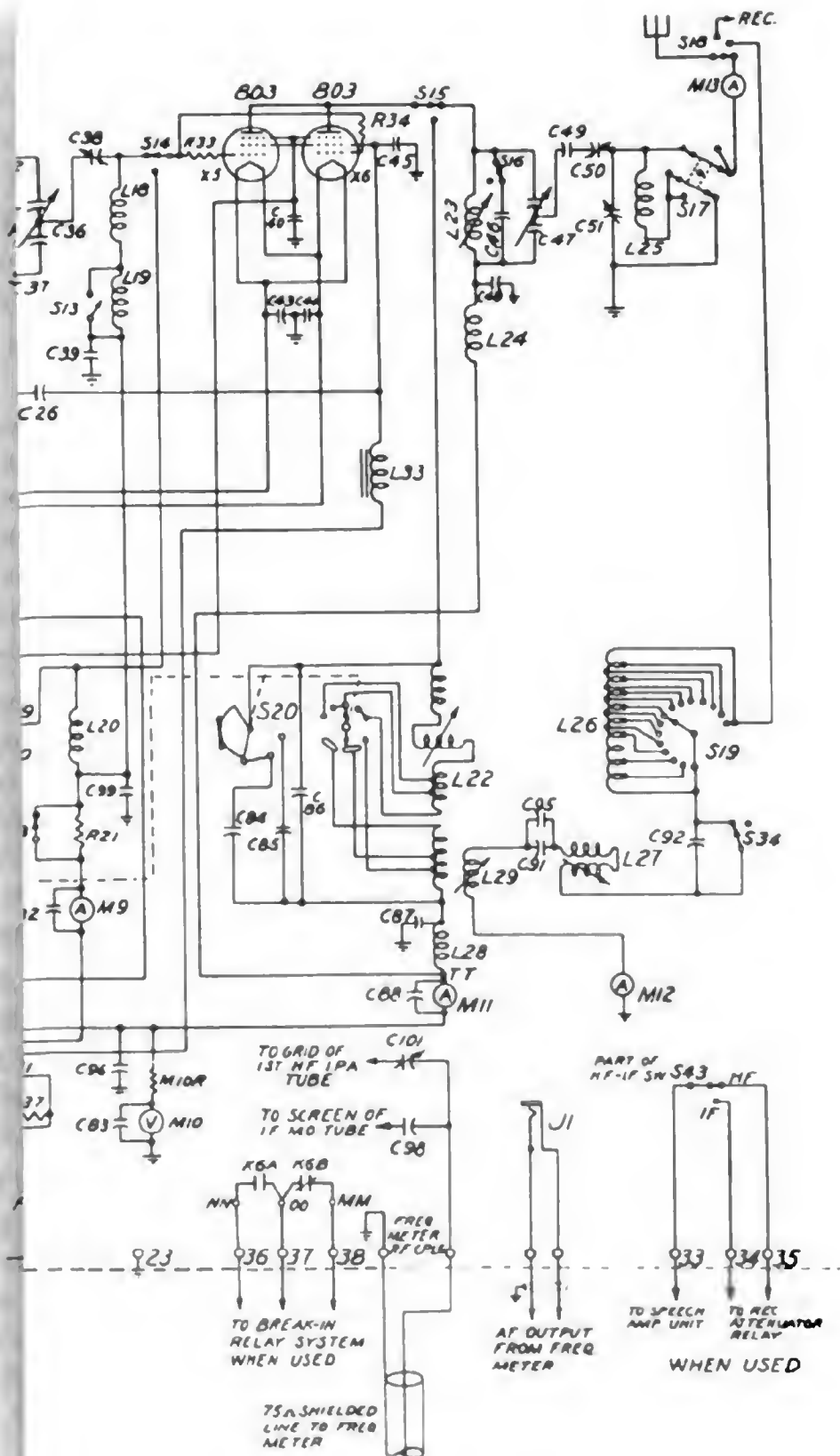


Figure 4-7.—Block diagram of the TBL transmitter.





and h-f master oscillators, except the tubes, are placed in a temperature-controlled oven with a constant temperature of 60° C.

The master oscillators are electron-coupled oscillators with their plate circuits tuned to twice the oscillator frequency. The plate-tank circuits are also enclosed in the temperature-controlled oven.

A schematic diagram of the TBL transmitter is shown in figure 4-8. The h-f oscillator grid circuit operates from 1000 to 2262.5 kc with the frequency of the grid circuit being doubled in the plate tank. The plate tank is called the DOUBLER CIRCUIT. Since the master oscillator frequency is always doubled in the plate circuit, the effective frequency coverage of the master oscillator is from 2000 to 4525 kc.

The frequency band of the master oscillator is covered in six ranges. Different combinations of the fixed capacitors in conjunction with the tapped inductor are used to obtain the different frequency ranges. A range switch selects the proper capacitors and tap on the inductor. The inductor is varied by moving a copper sleeve in or out of the coil to obtain a given frequency in the range selected.

A small variable capacitor C6 is a screw-driver adjustment used to make the oscillator frequency track with the dial calibration. It compensates for changes due to aging or replacement of components in the oscillator circuit.

The interelectrode capacity of a tube may change when space current flows through the tube, because the heat produced by this current may change the shape of the tube elements. As the oscillator stage in the TBL transmitter is keyed, the space current causes the capacity to change. To compensate for this change a special capacitor C100 is used. This is similar to the capacitor C62

used in the TBK oscillator which was discussed previously.

Capacitor C16 is an internal adjustment which is set to obtain sufficient coupling to the doubler circuit over the entire band of frequencies covered by the TBL. The oscillator is electron-coupled with the plate circuit always tuned to twice the oscillator frequency. The master oscillator is keyed by a set of relay contacts in the filament center-tap to ground. The first and second high frequency amplifiers use this center-tap also and hence are keyed along with the master oscillator. A resistor and capacitor are shunted across the keying contacts to suppress key clicks.

### **First H-F Amplifier**

The first high-frequency amplifier is used to isolate the master oscillator from the rest of the stages as well as to amplify the oscillator output and sometimes to double the frequency. For frequencies between 2000 and 4525 kc this stage is operated as a straight-through amplifier. Frequencies between 4000 and 9050 kc are obtained by doubling in this stage.

The first h-f amplifier receives fixed bias through choke L7 and resistor R10 from the bias voltage generator. Additional bias is obtained from grid current flow through R10. The plate circuit is series fed. Switch S9 is part of the frequency range switch which changes the frequency range of this stage. With S9 open, the range of the first h-f amplifier is 2000 to 4100 kc. With S9 closed, the range is from 4100 to 9050 kc.

Switch S4 in the grid circuit and switch S5 in the plate circuit are contacts of the H-F/I-F transfer switch. They connect this stage as an audio oscillator for m-c-w operation in the i-f range. Meter M5 measures the plate current of the first high-frequency amplifier when it is being used as an amplifier or doubler.

## **Second H-F Amplifier**

The second h-f amplifier is operated as a straight-through amplifier for frequencies between 2000 and 9050 kc and as a frequency doubler for frequencies between 9050 and 18,100 kc. The output of the first h-f amplifier is fed through capacitor C29 and appears across choke L14. Fixed bias for this stage is obtained from a voltage divider across the bias generator.

The tuned-plate circuit consists of a variable inductor L16 and capacitor C36 ganged together. A fixed capacitor C35 is switched in and out of the tank circuit depending on the position of the frequency range switch section S12. When the switch is closed, this stage tunes from 2000 to 4100 kc. When it is open, the stage tunes from 4100 to 18,100 kc. Switch contacts S10 in the grid circuit and S11 in the plate circuit are part of the H-F/I-F transfer switch. Meter M8 indicates the plate current of this stage and meter M7 indicates the filament voltage.

## **Power Amplifier**

The power amplifier receives its excitation from the second h-f amplifier through capacitor C38. The r-f voltage appears across chokes L18 and L19. For frequencies above 4100 kc, choke L19 is bypassed by S13 because at certain frequencies the combined inductance of the chokes together with their distributed capacitance would form a series resonant tank. If the chokes should resonate, high currents would burn them out. Resistors R33 and R34 in the grid circuit are parasitic suppressors.

If the final amplifier grid current should exceed the 90-milliampere maximum, additional bias can be obtained by opening the grid current switch S38. This places additional resistance in the grid circuit. Additional bias is then developed by the flow of grid current through R21. Meters M9 and M11 indicate the grid and the plate current of the final amplifier, respectively.

The plate tank is composed of a variable inductor L23, a variable capacitor C47, and a fixed capacitor C46. The variable inductor and variable capacitor are ganged together. Capacitor C46 is placed in the tank circuit by a section of the frequency range switch. With capacitor C46 in the tank circuit, the final amplifier tunes from 2000 to 4100 kc. With C46 out of the tank circuit, the stage tunes from 4100 to 18,100 kc. Switch S14 in the grid circuit and S15 in the plate circuit are part of the H-F/I-F transfer switch.

The final amplifier is always operated as a straight-through amplifier. A separate winding on the filament transformer T1 supplies filament voltage to the final amplifier. The center tap of the filament winding returns to ground through resistor R8 in parallel with choke L6. This filter causes the plate current of the final amplifier to build up gradually when the transmitter is keyed and prevents surges of plate current from causing thumps and clicks in nearby receivers.

Inductor L33 in the screen circuit serves no useful purpose for high frequency operation, but, when the i-f section is operating on m-c-w, the modulation signal is developed across this choke. For c-w operation a positive potential of about 30 volts is applied to the suppressor grids of the final amplifier through the C-W/M-C-W-PHONE switch S7. This voltage is obtained from a voltage divider across the 2000-volt output of the high voltage generator.

On voice operation switch S7 connects the suppressor grids to a negative bias obtained from the voltage divider across the bias generator. The bias selected reduces the unmodulated carrier output to one-fourth of the output on c-w. A reduction in power is necessary to prevent distortion of the modulated signal. An external speech input unit is needed on voice operation. The speech input unit, Navy type CRV-50254, has an output of 3.5 watts and pro-



vides the audio power necessary to suppressor-grid modulate the TBL transmitter.

The output of the final amplifier is coupled to the antenna tuning network through two capacitors connected in series. Capacitor C49 blocks the high d-c plate voltage from the tuning network. Capacitor C50 is the antenna coupling control. The antenna tuning circuit consists of a variable capacitor and a variable inductor. These may be connected for either current or voltage feed depending on the position of switch S17.

### **Intermediate Frequency Master Oscillator**

The intermediate frequency section of the TBL covers the frequency band of 175 to 600 kc. However, the frequency band covered by the master oscillator is one-half of the output frequency of the transmitter—that is, from 87.5 to 300 kc. The master oscillator frequency band is divided into seven ranges. A particular range is selected by switch S23, which places different values of fixed capacity and inductance in the oscillator tank circuit. Variometer L9 is tuned to the desired frequency within the range selected.

All of the frequency determining components except the oscillator tube are placed in the temperature-controlled oven. Plate current of the oscillator tube flows through inductors L9, L30, L8, and meter M2. When the H-F/I-F transfer switch is thrown to I-F, one of the contacts of switch S8 opens the relay K11. This reduces the filament voltage of the h-f oscillator and completes the filament circuit of the i-f oscillator.

The i-f section uses the same keying circuit as the h-f transmitter section. Meter M2 measures the plate current of both master oscillators depending on the position of the H-F/I-F transfer switch. A portion of the output of the master oscillator developed across capacitor C63 in the oscillator tank circuit is fed to the grid of

the intermediate frequency amplifier. The intermediate frequency amplifier and the second h-f amplifier use the same tube. As in the second h-f amplifier the grid circuit of this stage receives fixed bias from the voltage divider across the bias generator. The plate tank circuit, consisting of fixed capacitors, a fixed inductor, and a variometer, is always tuned to twice the oscillator frequency.

A frequency range switch S21 selects different values of capacity and inductance depending on the frequency range desired. The tank is tuned to the exact frequency with the variometer L15. The frequency range switches of the intermediate and final amplifiers are ganged. Output of the intermediate frequency amplifier is developed across capacitor C80 and inductor L20 in the grid circuit of the final amplifier.

### **Final I-F Amplifier**

The i-f and h-f final amplifiers use the same tubes. As mentioned previously this stage is always operated as a straight-through amplifier. The plate-tank circuit is composed of fixed capacitors, a tapped inductor, and a variometer. These components perform the same function as those in the h-f power amplifier plate circuit.

Meter M11 indicates final amplifier plate current. The output of the final amplifier is inductively coupled to the antenna tuning circuit by variometer L29, which is the i-f antenna coupling control.

### **M-C-W Oscillator**

As mentioned previously the first h-f amplifier tube is used as an audio oscillator to obtain m-c-w output when operating on i-f. Switches S4, S5, and S6 are operated by the H-F/I-F transfer switch. This oscillator produces an audio tone of 800 cps which modulates the final amplifier. The C-W/M-C-W-PHONE switch S7 completes the

filament circuit and places the audio oscillator in operation. The output of the audio oscillator is applied to the screen grids of the final amplifier through capacitor C26.

With switch S7 in the phone or in the c-w position, the filament voltage is removed from the audio oscillator and this stage is inoperative. Phone operation of the i-f section of the TBL transmitter is obtained in the same manner as with the h-f section. The external speech equipment suppressor grid modulates the final amplifier approximately 85 percent with an r-f output of 50 watts.

### Adjustments

The TBL transmitter has several front panel adjustments that are made when the transmitter is first turned on. Filament rheostat R47 is located on the front panel. This control is adjusted for the required filament voltage as indicated by the filament voltmeter M7. The main plate voltage control rheostat R41 (figure 4-5) is used to adjust the output of the high voltage generator. The plate voltage should be adjusted to the required value with the transmitter key closed. Opening emergency stop switch S24 removes all power from the transmitter including filament voltage and voltages for the temperature-controlled oven.

The most important adjustment made by the technician in tuning a transmitter is setting the master oscillator to the correct frequency. Communications may be seriously impaired or may fail completely if the transmitter is not set to the correct frequency. Accuracy of transmitter tuning is extremely important when using frequency shift keying and on communication nets.

Both the frequency meter and the master oscillator temperature-controlled oven must be allowed to come up to operating temperature before any adjustment is attempted. The frequency meter should be checked against a primary standard. When radio silence is broken and

positive communication is to be established, precious time can be saved and serious interference avoided by accurate tuning of the transmitter. Approximate dial settings are obtained from calibration charts, but the master oscillator is always tuned by using a frequency meter.

## TRANSMITTER TUNING UNDER RADIO SILENCE

A method of tuning communication transmitters during radio silence has been devised for all stages of the transmitter including the antenna. During radio silence no radiation from the transmitter is permissible. With all of the antennas grounded, the master oscillator, the intermediate amplifiers, and the final amplifier are tuned to resonance and then the transmitter is shut down. The antenna is now connected to the antenna terminal.

Adjusting the antenna circuit to resonance and coupling the antenna properly are accomplished by measuring the static noise picked up by the transmitter antenna. A receiver tuned to the output frequency of the transmitter is loosely coupled to the final amplifier plate lead to measure the noise voltage. If the receiver has no output meter, an a-c voltmeter can be used to measure the output of the receiver.

The final amplifier antenna controls are adjusted for maximum noise voltage as indicated by the output meter. A resistor equal to the load resistance of the final amplifier is connected from the final amplifier plate to ground. Proper antenna coupling is obtained by adjusting the coupling control until the noise voltage drops to one-half its value before the resistor was inserted.

The receiver may be connected through a coaxial line and a small capacitor to the final amplifier plate lead. On the higher frequencies a few turns of wire around the plate lead will provide sufficient coupling. The receiver automatic volume control should be off.

If the load resistance of the final amplifier is not

known, it can be determined by loading the transmitter normally at some time when radio silence is not in effect. Shut down the transmitter and connect the receiver to the final amplifier plate lead. Adjust the receiver for a convenient output. Place different values of resistance from plate to ground until the noise voltage drops to one-half the original meter reading. The resistance that drops the noise voltage to one-half its original value is the plate load resistance. The resistor is removed after the plate load resistance has been determined.

Now the antenna can be tuned to any frequency within the limits of the transmitter without any radiation from the antenna. The final amplifier and antenna tuning are adjusted for maximum noise. Then the gain of the receiver is adjusted to give a convenient meter reading. The resistance is then reconnected. If the reading is greater than one-half the original reading, the coupling is too tight. If the reading is less than one-half, the coupling is too loose. The accuracy attainable with this method of tuning depends on the steadiness of the noise and the noise level. With sufficient practice tuning by this method can be accomplished quite easily.

## TROUBLE-SHOOTING

Most of the failures encountered in electronic equipment are caused by defective tubes or fuses and open interlocks. A valuable aid in trouble-shooting is front panel indications. By observing the meters and panel lights, the trouble can usually be isolated to a certain stage quickly.

Suppose that the equipment has no power. The first check is testing the main power fuses. Low bias voltage or no bias voltage will show up on the bias meter. Also, the bias voltage is used to excite the high voltage generator field. If the bias voltage is not present, there will be no high voltage output from the generator.

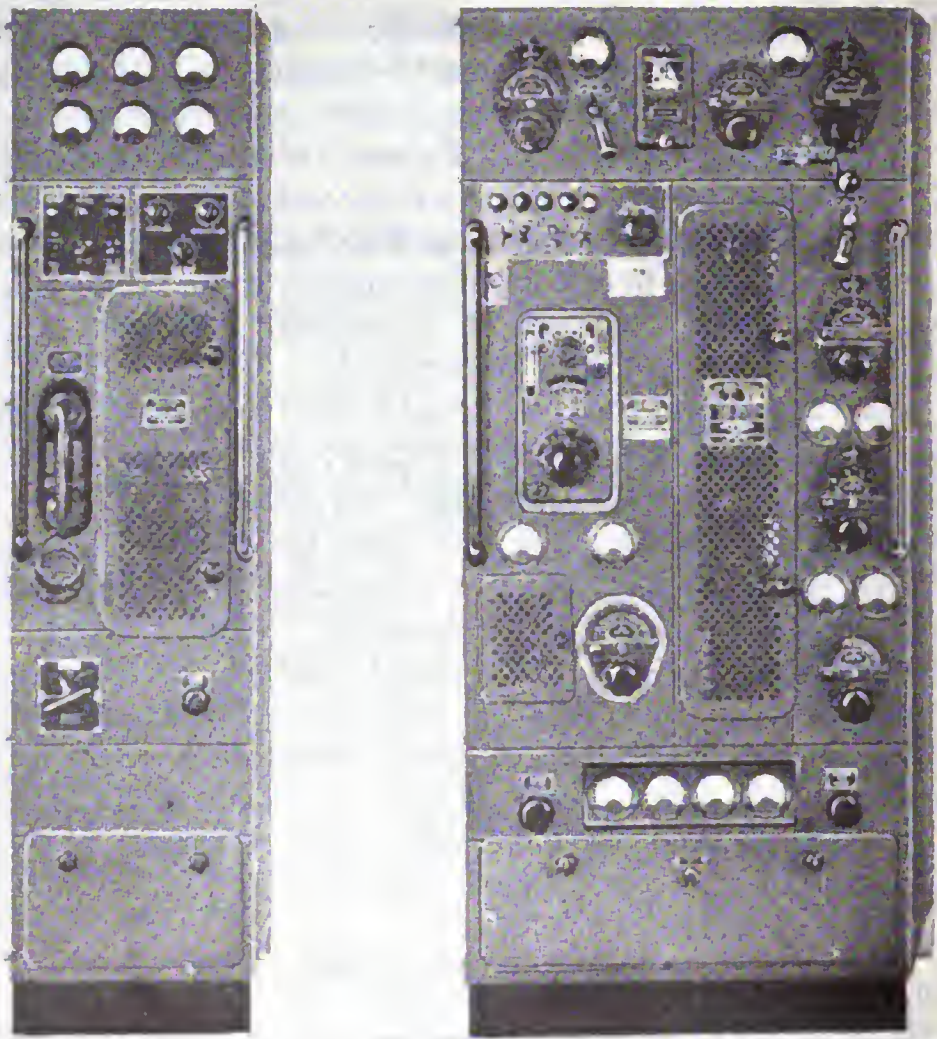


Figure 4-9.—TBM transmitter.

### TBM AND TBK TRANSMITTERS

The TBM and TBK transmitters are the same except that the TBM is supplied with a modulator unit. Figure 4-9 is a photograph of the TBM transmitter. The r-f sections of the TBM and TBK transmitters are basically the same as the high-frequency section of the TBL transmitter.

The TBK and the TBM have a frequency range of

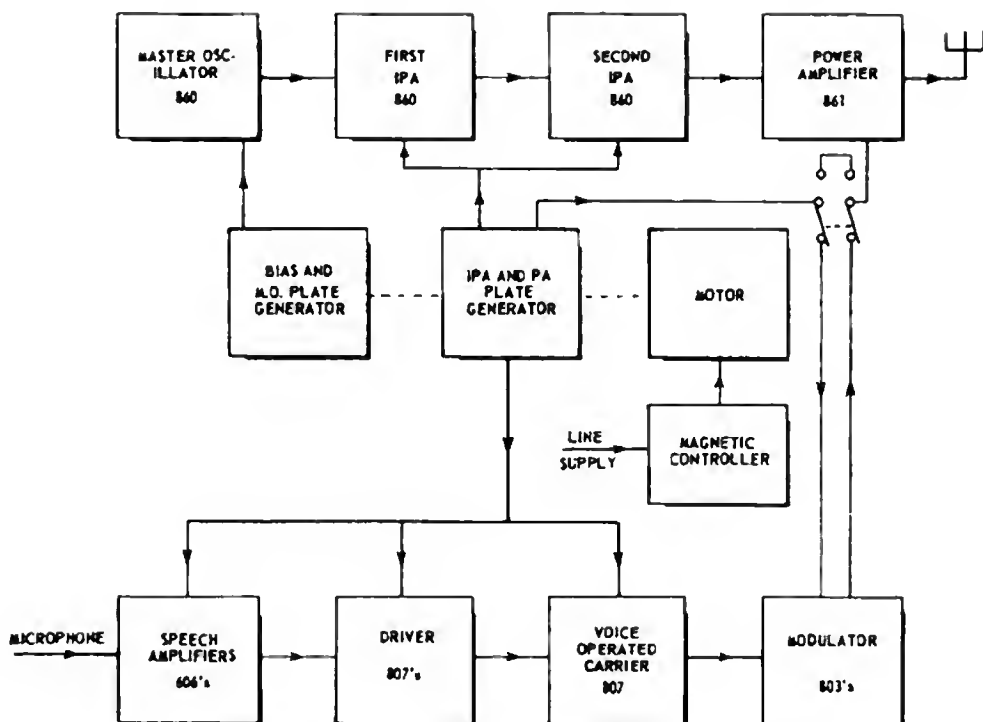


Figure 4-10.—Block diagram of the TBM transmitter.

2000 to 18,100 kc. A HIGH-LOW POWER switch on the front panel is used to switch out the final amplifier and connect the antenna to the second intermediate amplifier tube. In the LOW position the transmitter has an output of 75 watts in the frequency range of 2000 to 9050 kc using c-w only. When the modulator is in operation, the operator can select c-w, voice or m-c-w emission. The power output for voice or m-c-w emission is 350 watts. The c-w output is 500 watts.

A block diagram of the TBM is shown in figure 4-10. The master oscillator of this transmitter is described in the first part of this chapter.

The first intermediate amplifier is operated straight through for transmitter output frequencies between 2000 and 4525 kc and as a frequency doubler for frequencies between 4000 and 18,100 kc. In the 4000 to 18,100 kc position of the frequency range switch part of the inductance in the plate tank of the first intermediate am-



plifier and the final amplifier grid circuit is bypassed. Also, the fixed capacitors in the plate tank of both the second intermediate and the final amplifiers are removed from the circuit. For operation in the 2000- to 4000-kc range the entire inductance and fixed capacity are placed in the grid and plate circuits.

The second intermediate amplifier is used straight through on frequencies between 2000 and 9050 kc and as a doubler for frequencies between 9050 and 18,100 kc. The second intermediate amplifier can be used as the final amplifier when the high-low power switch is thrown to the LOW POWER position. This switch disconnects all voltages from the final amplifier tube and connects the output of the second intermediate amplifier to the antenna tuning circuit. The frequency range for low power operation is from 2000 to 9050 kc with an output from the transmitter of 75 watts on c-w only.

The final amplifier is operated straight through on all frequencies covered by the transmitter. The first and second intermediate amplifier and the final amplifier are operated class-C for efficient operation. The cut-off bias needed for these stages is obtained from the bias generator.

The TBK-11 has a vacuum-tube keyer. A simplified schematic diagram of this circuit is shown in figure 4-11. The vacuum-tube keyer is used in conjunction with the LAND-LINE CONTROL UNIT. This unit is designed to control the transmitter with signals received from a remote point over telephone lines.

On shore stations, transmitters are sometimes placed several miles from the operating controls. The land-line control unit is mounted near the transmitter, and telephone lines are used to connect this unit to the remote operating position. By depressing the remote key, the transmitter is turned on and will operate as long as regular keying takes place. If regular keying is stopped, a



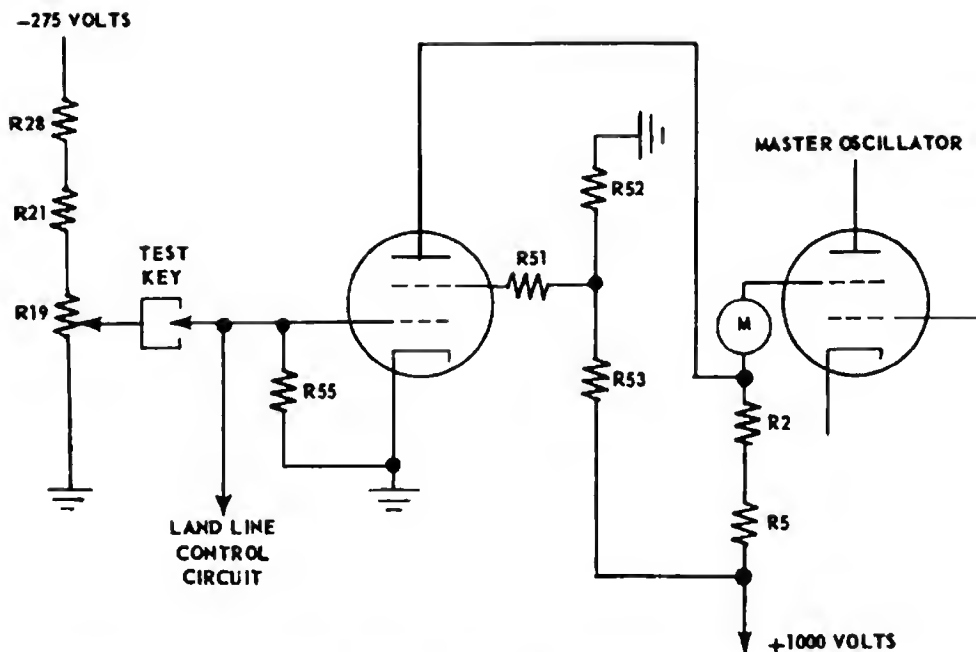


Figure 4-11.—Simplified schematic diagram of the vacuum-tube keyer.

timing device causes the transmitter to shut down. The land-line control unit is not described here, but the way its output keys the transmitter is discussed.

Refer to figure 4-11. Notice that the plate of the keyer tube is effectively connected in parallel with the screen grid of the master-oscillator tube. The screen voltage for the keyer tube is obtained from a voltage divider across the 1000-volt supply to ground. The keyer tube draws maximum current when there is no output from the land-line control circuit and the test key is open. The current is maximum because there is no bias on the control grid. The screen potential of the oscillator tube falls to a low value and the oscillator will not oscillate.

If the test key is closed, a negative bias from the bias generator cuts off the keyer tube. The normal master oscillator screen voltage is restored and the oscillator has normal output. The land-line control circuit supplies negative pulses of voltage to the keyer tube to place the master oscillator in operation. The negative pulses of voltage are reproductions of the original keying pulses from the hand

key at the remote control point. When vacuum-tube keying is not desired, a switch in the filament lead disconnects the keyer tube.

### TBM Modulator

The TBM modulator is designed to plate modulate the final amplifier of the transmitter. Although it is a separate unit, the modulator is interconnected with the transmitter and receives its power from the transmitter. A schematic diagram of the CAY-50065 modulator is shown in figure 4-12. The portion of the diagram enclosed in broken lines is the modulator unit.

The first stage is a push-pull voltage amplifier. RX402 and RX403 are crystal diodes which clip any high peaks of voltage appearing across the input transformer. R401 is a *T*-pad attenuator that determines the amount of signal coupled to the grid of the voltage amplifier. The output of this amplifier is transformer coupled to the driver stage. When the emission selector switch is in the MCW position, the driver stage, VT403 and VT404, becomes an audio oscillator. Meter M401 indicates the plate current of the voltage amplifier and meter M402 indicates the plate current of the driver stage.

Tube VT409 is a compressor-limiter. A winding on transformer T404 couples a small part of the output of the driver stage to the plate of VT409. The left-hand section of VT409 is conducting and a voltage drop appears across resistors R405 and R406. This voltage drop adds to the fixed negative bias already on the input stage. As the amplitude of the audio signal increases up to the amount needed to drive the modulator tubes sufficiently to produce 100-percent modulation, the bias increases proportionately.

If the audio signal is sufficient to drive the modulator tubes to produce more than 100-percent modulation, the right-hand section of VT409 conducts. Thus additional





bias is supplied to VT401 and VT402 to reduce the amplifier gain. Potentiometer R432 is factory adjusted to obtain satisfactory operation of the compressor limiter.

The modulator tubes VT405 and VT406 are operated with zero bias. The primary of the modulation transformer is made in two sections, one section for each tube in order to make individual metering possible. Meters M403 and M404 indicate the plate current of these tubes. No direct current flows through the secondary winding because capacitor C408 isolates the modulation transformer from the plate current of the final amplifier.

The audio output of the modulator is coupled through capacitor C408 and developed across inductor L404, which is in series with the power amplifier plate lead. The modulation signal adds to and subtracts from the final amplifier plate voltage. Diode VT407 limits the positive swing of the power amplifier plate supply voltage. A precaution against high peaks of voltage is provided by spark gaps across the primary windings and across inductor L404. Meter M406 is the filament voltmeter. Meter M405 is the PERCENTAGE-MODULATION meter used only during voice operation. When switch S405 is in the CW position, M405, T406, and L404 are bypassed by switch contacts.

In the MCW position S405 bypasses only M405 and T406. The modulation meter will not go to zero when S405 is in either the CW or the MCW position, but will remain somewhere near half-scale. Rheostat R495 is used to adjust the filament voltage to the required 10 volts. By placing S405 in either the voice or the MCW position, power is supplied to a rectox unit RX401. This rectifier supplies d-c voltage to the microphone and to the keying relay K401C when the switch is in the VOICE position. Closing the push-to-talk button (not shown in the figure) on the handset energizes K401C and completes the keying circuit in the transmitter.

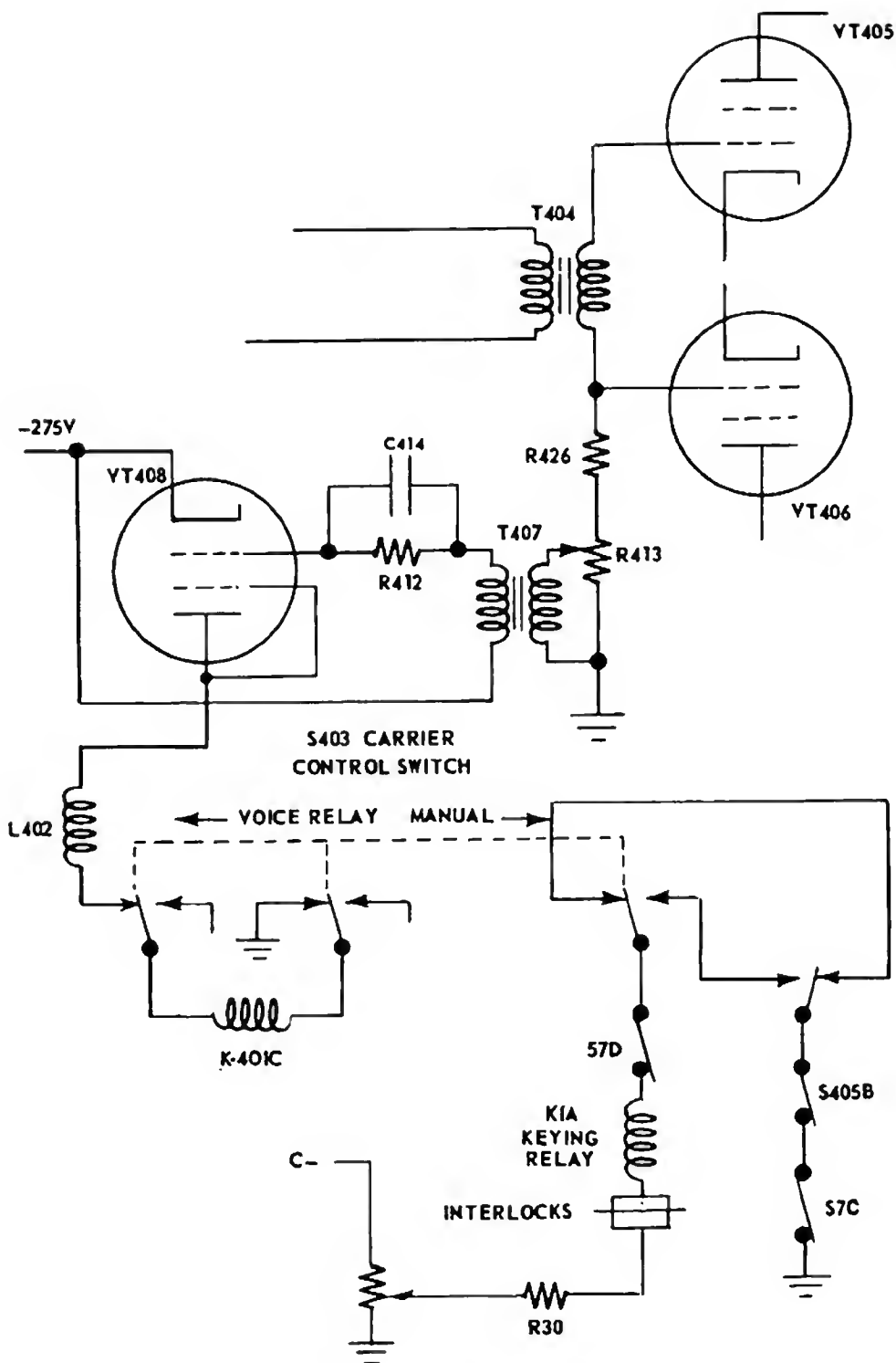


Figure 4-13.—Simplified schematic diagram of the voice-operated relay.

A means of keying the transmitter other than with the push-to-talk button is turning the carrier-control switch S403 to the VOICE-RELAY position. When the voice-operated relay is used, it is possible to key the transmitter merely by speaking into the microphone. A simplified schematic diagram of the voice-operated relay is shown in figure 4-13.

The switches are shown in the keyed position in the diagram. A small part of the audio voltage is coupled through resistor R426 and appears across potentiometer R413 and transformer T407. The audio voltage causes grid-leak bias to be developed across the *R-C* combination R412 and C414 and cuts off VT408 plate current. With VT408 cut off, no current flows through relay K401C and this relay is in the position indicated.

The voice-operated relay keys the transmitter 0.025 seconds after the first syllable is spoken into the microphone. Potentiometer R413 is the VOICE-RELAY-SENSITIVITY CONTROL. With correct adjustment of this control, normal room noises should not cause the transmitter to be keyed. However, speaking into the microphone in a normal manner causes the relay circuit to operate. If speech stops for about 0.2 seconds or longer, capacitor C414 discharges and VT408 conducts. Relay K401C is energized and the ground return of the keying relay in the transmitter is interrupted.

Switch S401, figure 4-12, is operated by removing the handset on the modulator from its cradle. The switch is shown with the handset removed from the cradle. In this position the audio signal from a remote radiophone unit cannot enter the modulator. The TALK SWITCH S404 performs the same function as the push-to-talk switch on the handset. The *T*-pad attenuator R401 is adjusted until the desired amount of modulation is obtained.

## LOW- AND MEDIUM-FREQUENCY ANTENNAS

The lower the frequency, the greater the physical length of the antenna required for efficient radiation. As the frequency of operation is lowered, it becomes impossible to construct an antenna a half or even a quarter wavelength long. However, by several methods a relatively short antenna can be made to appear as a quarter wavelength by placing coils and capacitors in series with the antenna. This is called **LOADING**.

Shipboard antennas used at the lower frequencies are generally a long wire with some means of changing the electrical length to the frequency of operation. Unlike the antennas on shore stations, which operate on only one frequency, shipboard antennas must be used on several different frequencies.

A common means of increasing the electrical length of antennas used at broadcast stations is top loading. Two types of top loading are shown in figure 4-14, one using a capacitor and the other an inductor. The capacitor is formed by a spider placed on top of the antenna. The spider acts as one plate and the earth acts as the other plate. In a capacitor a charging current flows when a potential is applied between its plates. In this case, the charging current flows through the antenna. Since the radiation from an antenna depends on the amount of current flowing through it, the capacitor makes the antenna appear longer and also increases the radiation from the antenna.

An inductance placed approximately one-twentieth of a wavelength from the top end of an antenna makes the antenna appear electrically longer. This method of loading is sometimes used, but, due to the difficulty of placing an inductance in series with a steel tower, it is not very popular. No matter what system of loading is used, the principal reason for loading is to get a greater average



current flowing in the antenna and thereby obtain a greater amount of radiation from the antenna.

For efficient operation of the quarter-wave Marconi antenna, the ground losses must be made as low as possible. As shown in figure 4-14, a capacity exists between the antenna and the earth. The charging current for this

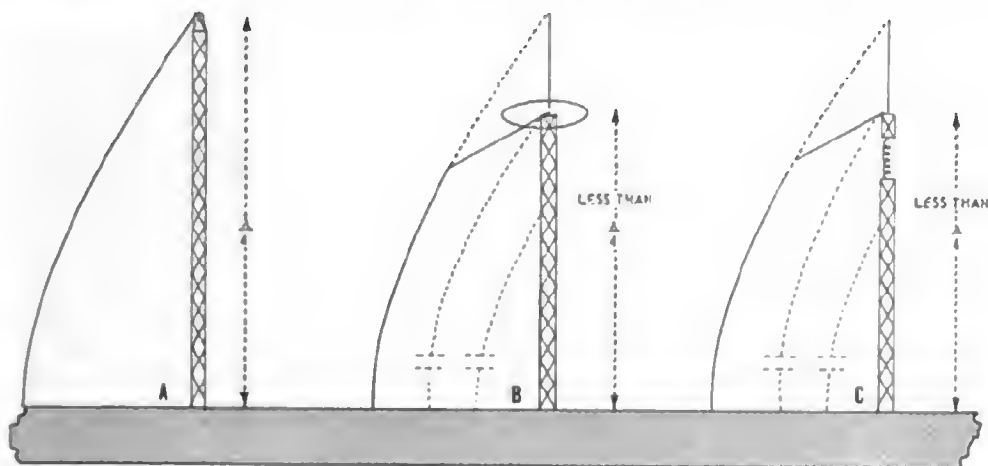


Figure 4-14.—Vertical antennas. A, No loading, B, capacity top loading, C, inductance top loading.

capacity flows through the earth to the base of the antenna. If the conductivity of the earth is low, a considerable loss of power occurs. Ground losses may be reduced by ground radials.

Ground radials are large-diameter copper wires buried a few feet below the surface of the earth. They provide a low resistance path for the antenna current. All of the radials are connected to the base of the antenna. An artificial ground is sometimes used when the soil is especially dry and rocky. The artificial ground called a COUNTERPOISE, is a network of wires a few feet above the earth and insulated from the earth. The wires form a screen beneath the antenna. To be fully effective, spacing of the wires should be less than the height of the counterpoise above the earth.

With the base of the antenna directly grounded, the

antenna must be shunt-fed. A shunt-fed Marconi antenna is shown in figure 4-15. It works equally well with either capacity or inductive top loading. The point to which the transmission line is connected is determined experimentally by moving the line up and down the antenna until the desired loading is found. The variable capacitor tunes

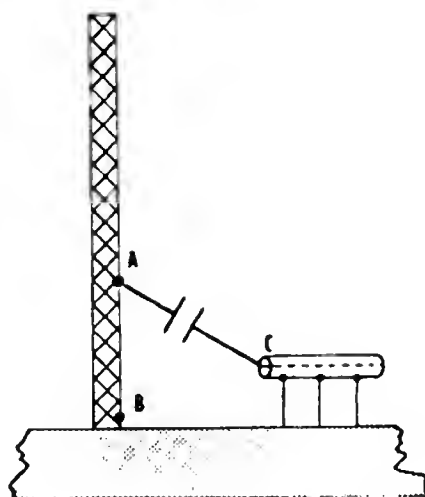


Figure 4-15.—Shunt-fed Marconi antenna.

out the inductive reactance and brings the antenna into resonance. Care must be taken to insure that the section of earth from B to C, in figure 4-15, has low losses. Sometimes this section is a wire either buried or run above the earth.

A more familiar type of tuning is shown in figure 4-16. The diagram shows the antenna tuning system of the TBK-13 transmitter for current feed. The variable capacitor C42 and the variable antenna inductor are used to vary the electrical length of the antenna.

The antenna system is tuned in the following manner. With the coupling capacitor set at minimum capacity, the final amplifier is resonated. Then capacitor C42 and the antenna inductor are tuned for maximum indication on the antenna current meter M1. The antenna now appears as a pure resistance to the final amplifier. The

coupling capacitor is increased in small steps until the required loading of the final amplifier is obtained. However, each time the coupling capacitor is changed, the final amplifier and the antenna tuning must be resonated.

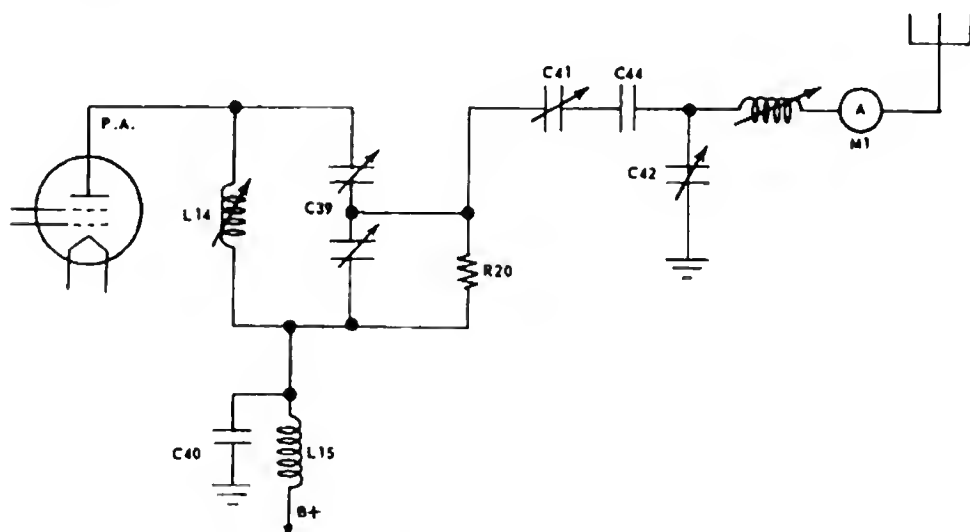


Figure 4-16.—TBK-13 antenna tuning using current feed.

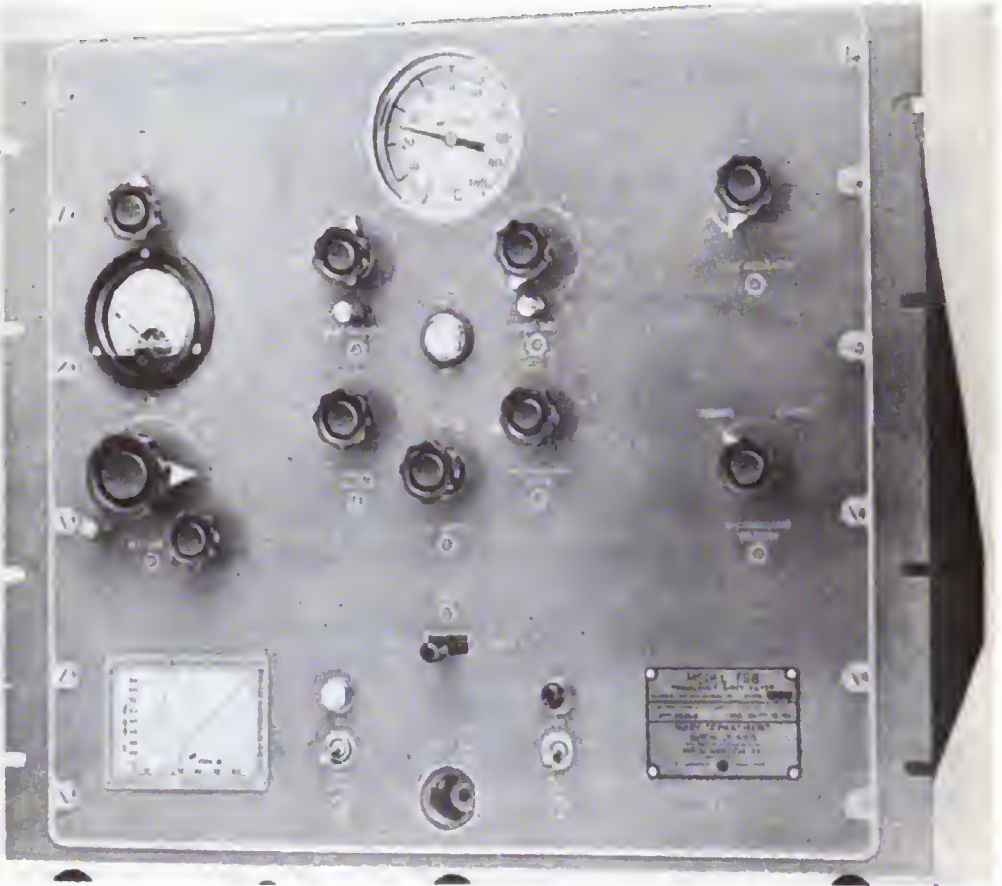
Care must be taken not to overcouple with capacitor C41. After the final amplifier and the antenna circuit are resonated, the final amplifier sees a pure resistive load and the best transfer of energy from the final amplifier to the antenna is obtained.

## FSB FREQUENCY-SHIFT KEYER

The FSB frequency-shift keyer is designed to key a transmitter by the frequency-shift method. A photograph of the FSB is shown in figure 4-17. It consists of a 13-tube, 2-watt exciter which produces a carrier capable of being shifted between two distinct frequencies in accordance with the output of a teletypewriter.

The frequency-shift keyer is connected to an associated transmitter. The output of the master oscillator of the transmitter is fed into the FSB. A low-frequency oscil-

lator in the keyer has a reactance tube connected across its tank circuit. The keying pulses from the teletypewriter change the current through the reactance tube and cause the frequency of the low-frequency oscillator to change. The output of the low-frequency oscillator is mixed with



**Figure 4-17.—FSB frequency-shift keyer.**

the input from the master oscillator of the transmitter. The sum frequency is amplified and supplied back to the stages following the master oscillator in the transmitter.

The frequency shift is usually 425 cycles below the assigned carrier frequency for a space and 425 cycles above the assigned carrier frequency for a mark. A polar keying signal from the teletypewriter must be positive for a space and negative for a mark.

## Limiter, Keyer, and Reactance-Tube Circuits

A simplified schematic diagram of the keying-pulse limiter, keyer, and reactance tube is shown in figure 4-18. The keying-pulse limiter tube has a positive bias on its cathode and it conducts only if a negative mark signal is applied to the cathode. When a steady space signal is present, the keying limiter does not conduct.

A positive bias obtained from a voltage divider in the keyer plate circuit is connected to the grid of the keyer causing it to conduct heavily. The cathode current of the keyer flows through the BASIC SHIFT control and also through a voltage divider in the grid circuit of the reactance tube. The voltage developed across the voltage divider is positive with respect to ground and, since it is applied to the grid of the reactance tube, the tube conducts heavily. The amount of current through the reactance tube determines the frequency shift of the low-frequency oscillator. The frequency output of the low-frequency oscillator is 199.150 kc for a space.

A mark signal of at least  $-50$  volts placed on the cathode of the keying-pulse-limiter cathode causes this tube to conduct and bias the keyer to cut-off. If the keyer is cut off, the positive bias on the grid of the reactance tube is removed and the plate current of the reactance tube decreases. This lowers the capacity reflected into the low-frequency oscillator tank circuit and increases its frequency to 200 kc. Thus the frequency of the low-frequency oscillator is shifted a total of 850 cycles from a space to a mark.

A phase modulator incorporated in the FSB may be used to phase modulate the signal from the low-frequency oscillator with a 200-cycle signal. This is sometimes done to improve the signal-to-noise ratio at the receiving station under conditions of multipath propagation.



## 200-Kc Oscillator and Balanced Mixer Amplifier

Figure 4-19 is a simplified schematic diagram of the 200-kc oscillator and the balanced mixer amplifier. The output of the 200-kc oscillator is used as a push-pull input to the balanced mixer amplifier. The input from the transmitter master oscillator also is coupled into this stage and is placed on a pair of grids connected in parallel.

The signal from the 200-kc oscillator will not appear in the output of the balanced mixer amplifier because of the push-pull arrangement. However, three different frequencies appear in the plate circuit: (1) The signal from the master oscillator, (2) the difference frequency of the master oscillator and the 200-kc oscillator, and (3) the sum frequency of the master oscillator and the 200-kc oscillator. The plate-tank circuit of the balanced mixer amplifier is tuned to the sum frequency. The sum frequency is coupled to the grid of the r-f amplifier.

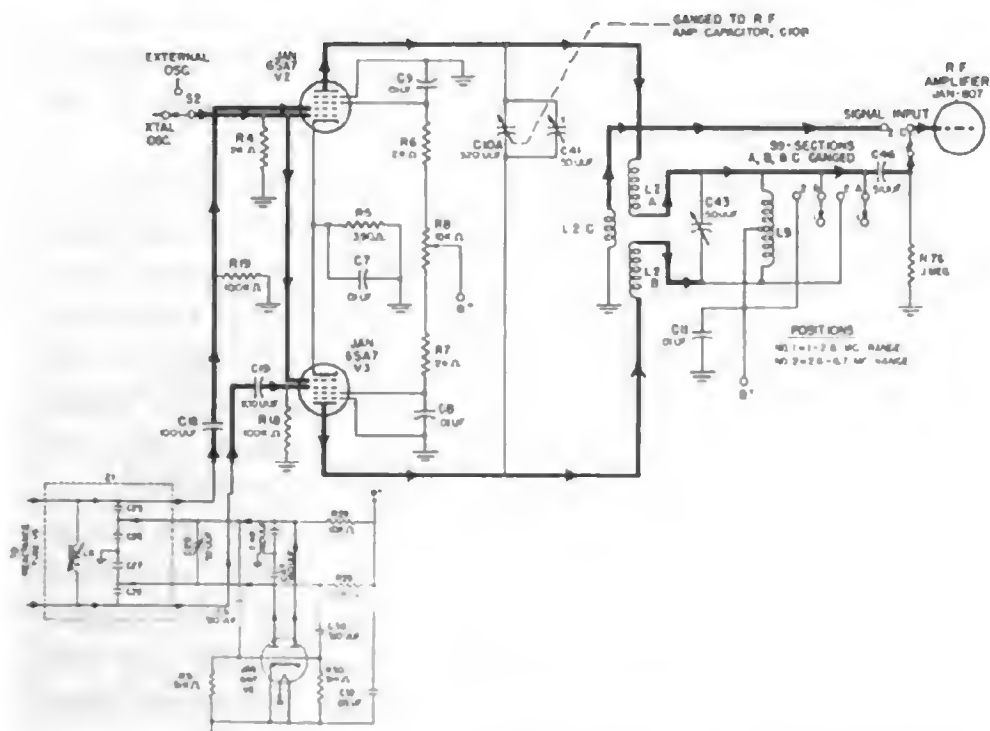


Figure 4-19.—Simplified schematic diagram of the 200-kc oscillator and the balanced mixer amplifier.

With switch S9 in the number 1 position the tuned grid circuit is tuned from 1.0 to 2.6 Mc. In the number 2 position it tunes from 2.6 to 6.7 Mc.

A schematic diagram of the r-f amplifier is shown in figure 4-20. This stage amplifies the output of the balanced mixer amplifier to about two watts. The output is supplied back to the transmitter. The RANGE SWITCH S9 selects the required coupling circuit to the r-f amplifier and also the tank circuit for the r-f amplifier. The output of the FSB is taken from jack J3. Part of the output may be coupled to a frequency meter through jack J2.

### Provisions for Frequency Multiplication

It has been assumed in the foregoing explanation that no frequency multiplication follows the output of the FSB. However, provisions have been made so that the output can be multiplied. If the output of the FSB were multiplied, the frequency shift of the carrier also would be multiplied. This is not desirable because the frequency of the carrier would be shifted beyond the range of the receiving equipment.

The MULTIPLICATION-FACTOR switch S3, figure 4-18, reduces the amount of frequency shift of the 200-kc oscillator by reducing the positive bias on the reactance tube. If the output of the FSB is to be doubled, the frequency shift must be one-half as great. If it is to be tripled, the frequency shift must be one-third as great. The phase modulation frequency is reduced in the same ratio by another section of the multiplication-factor switch.

The frequency of the master oscillator of the transmitter is added to the frequency of the 200-kc oscillator. For a given output frequency of the FSB the master oscillator frequency must be less. To compute the frequency of the master oscillator use the following equation:

$$\text{carrier freq.} + 0.425 \text{ kc} - 200 \text{ kc} = \text{master oscillator freq.}$$



If the output is to be multiplied, the multiplication-factor switch must be placed in the position corresponding to the number of times the output is to be multiplied and the master oscillator frequency may be computed by using the following equation:

$$\frac{\text{carrier freq.} + 0.425 \text{ kc} - 200 \text{ kc}}{\text{freq. multiplication factor}} = \text{master oscillator freq.}$$

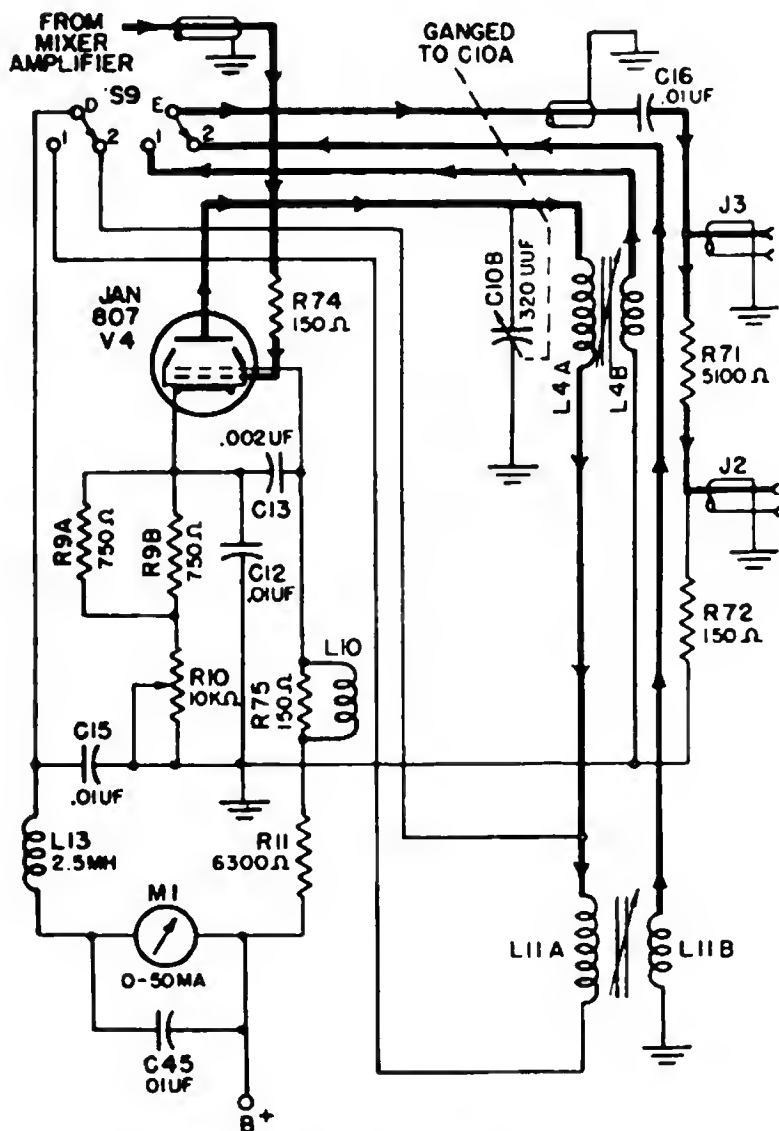


Figure 4-20.—Schematic diagram of the r-f amplifier.

In practice the master oscillator frequency need be only within one kilocycle of the frequency computed from the equation because the frequency of the 200-kc oscillator can be varied a small amount with capacitor C29.

### Adjustments

The basic shift control is used to adjust the frequency of the 200-kc oscillator to 199.150 kc for a steady space signal. The MARK FREQUENCY control C29 is used to adjust the 200-kc oscillator until the output frequency of the FSB is 425 cps above the input frequency of the master oscillator for a steady mark (figure 4-19).

A test key is provided so that the FSB can be placed in a steady mark or a steady space condition in order to measure the frequency of its output when keying signals from the teletypewriter are not present. When the test key is in the SPACE position, a high positive bias is placed on the cathode of the keying-pulse limiter to be sure that no negative mark signals cause this tube to conduct. In the mark position the voltage divider in the grid circuit of the reactance tube is shorted to ground and no bias is placed on the grid. A crystal oscillator is incorporated in the FSB. It may be used in place of the transmitter master oscillator.

### QUIZ

1. What is continuous wave (c-w) transmission?
2. What is modulated continuous wave (m-c-w) transmission?
3. What is teletype transmission?
4. What is on-off keying as used with teletype transmission?
5. What is frequency shift keying as used with teletype transmission?
6. What is two-tone keying as used in teletype transmission?
7. How is transmitter frequency drift in the variable master oscillator minimized?

8. Why does the Navy use electron-coupled oscillators in most of its transmitters?
9. State an advantage derived from operating the plate circuit of a master oscillator at twice the operating frequency of the grid circuit.
10. What effects would be noted if contact K13B, in figure 4-5, were stuck in the closed position (TBL transmitter)?
11. Does opening the emergency stop switch, S24, of the TBL transmitter render it completely safe for servicing operations (figure 4-5)?
12. In the TBL transmitter the bias supply is used as excitation for the high voltage section of the motor-generator. What advantage does this system offer?
13. If the output frequency of the TBL transmitter were 13,476 kc, to what frequency would the grid circuit of the master oscillator be tuned?
14. (a) What is the effect on grid current in the final amplifier of the TBL transmitter if switch S38 (figure 4-8) is opened?  
(b) What electrical change in the circuit causes this effect?
15. How would an open filament in tetrode X2 (figure 4-8) of the TBL transmitter affect m-c-w operation?
16. The second intermediate amplifier of the TBM transmitter is used as a doubler for what range of transmitter frequencies?
17. With the high-low power switch of the TBM transmitter in the low position, what tube supplies r-f power to the antenna?
18. What is the basic difference between the keying methods used in TBL and TBM transmitters?
19. What circuit in the CAY-50065 modulator resembles the a-v-c circuit of a superheterodyne receiver?
20. What is the difference between a counterpoise and a ground radial?
21. Why would a quarter-wave vertical antenna not be a good radiator of r-f energy when working against dry, sandy soil?
22. Under normal operating conditions, at what time does the FSB frequency shift keyer allow the designated center frequency to be transmitted?
23. What is the purpose of switch S3 in the reactance tube circuit of the FSB frequency shift keyer?



# CHAPTER

# 5

## V-H-F AND U-H-F TRANSMITTERS

### OPERATIONAL USE OF THE V-H-F AND U-H-F BANDS

The very-high-frequency (v-h-f) band extends from 30 to 300 megacycles. This band is not used extensively by the Navy for communications purposes. Portions of the v-h-f band are used for airborne communications. The TDQ and TBS transmitters and the MBF transmitter-receiver operate in this band.

Dependable communications at distances slightly greater than the horizon can be obtained with the above equipment. The ionosphere does reflect a small amount of the lower frequencies of the v-h-f band so that long-range transmissions are sometimes possible in this band. Among the services using the v-h-f band are early-warning radar, IFF, television, and f-m broadcast stations.

### PROPAGATION

The ultra-high-frequency (u-h-f) band includes the frequencies between 300 and 3,000 megacycles. The low end of this band is used for communications and portions of the high end are used for radar. Several advantages are gained by using frequencies in the u-h-f band. Because the ionosphere is not dense enough to reflect a sky wave of u-h-f radiation, most transmissions are limited to the line of sight or the direct wave.

However, u-h-f transmissions are not always limited

to the line of sight. Sometimes the lower atmosphere is composed of horizontal layers in which the temperature and moisture content vary in a manner that is not normal. If the variation is sufficiently great, ducts may be formed. The ducts may act as huge waveguides and radio and radar waves may travel far beyond the horizon. This phenomenon is known as SUPERREFRACTION.

Line-of-sight reception is very satisfactory and is relatively free from static and fading. Another advantage is the secrecy of transmissions due to the small area normally covered. The normal range of transmissions is somewhat extended because of refraction and the range is about fifteen percent beyond the visible horizon.

Navy communications in the u-h-f band are primarily ship-to-ship circuits. Teletype with two-tone keying is also available for use with the TDZ transmitter. The TDZ transmitter is discussed in this chapter.

## WEIGHT AND SPACE FACTORS

Transmitters operating in the v-h-f and u-h-f bands have components which are much smaller than those used in low frequency transmitters. Instead of the usual coil and capacitor that make up a tank circuit, the v-h-f and u-h-f transmitters use tuned lines. The power output requirements of the u-h-f transmitters generally are much less than the output of low-frequency transmitters because a smaller area is covered. This reduces the size of power supply components and also reduces the weight of the equipment. Another characteristic feature of the higher frequency bands is the reduction in the size of the antenna required. The reduction in the weight of the equipment and the size of the antenna is particularly important in the design of equipment used in aircraft.

## TUNING TECHNIQUES

Most of the transmitters operating in the u-h-f band are crystal controlled. However, crystals having a funda-

mental frequency in the u-h-f band are not practical because of physical restrictions such as difficulty in grinding and extreme fragility. Therefore, the transmitter usually employs a low frequency crystal oscillator followed by a number of frequency multipliers, the number depending on the output frequency desired. In the TDZ transmitter the crystal frequency is multiplied 54 times. Multiplier stages must be accurately tuned to the correct harmonic frequency. Experienced personnel are required to change frequencies.

However, in the TDZ transmitter an electrically controlled mechanical system is used to position the tuning controls. Frequencies are set initially by manually tuning each stage to the crystal frequency or to the proper harmonic frequency while observing the meters on the front panel of the transmitter. The procedure is the same as for any multistage transmitter. Once preset, frequencies can be selected easily by inexperienced personnel, using either a telephone type dial on the transmitter or a similar dial on the remote control unit.

## MODEL TDZ TRANSMITTER

The TDZ is a crystal-controlled, automatically-tuned transmitter covering the frequency range of 225 to 400 megacycles. A photograph of the TDZ transmitter is shown in figure 5-1. Two types of modulation are available, either voice or m-c-w. The unmodulated output of the transmitter is 20 to 35 watts depending on the frequency.

### Autotune System

Automatic tuning of the TDZ transmitter is accomplished by using an electromechanical arrangement known as the AUTOTUNE SYSTEM. The autotune system is an electrically controlled means of mechanically adjusting the angular positions of tuning elements such as variable ca-

pacitors, variometers, rotary switches, cam-operated switches, and tuning slugs. The channels are preset initially by loosening the locking bars on the tuning heads, setting the heads manually, and then tightening the locking bars again.

The tuning heads adjust the angular positions of worm

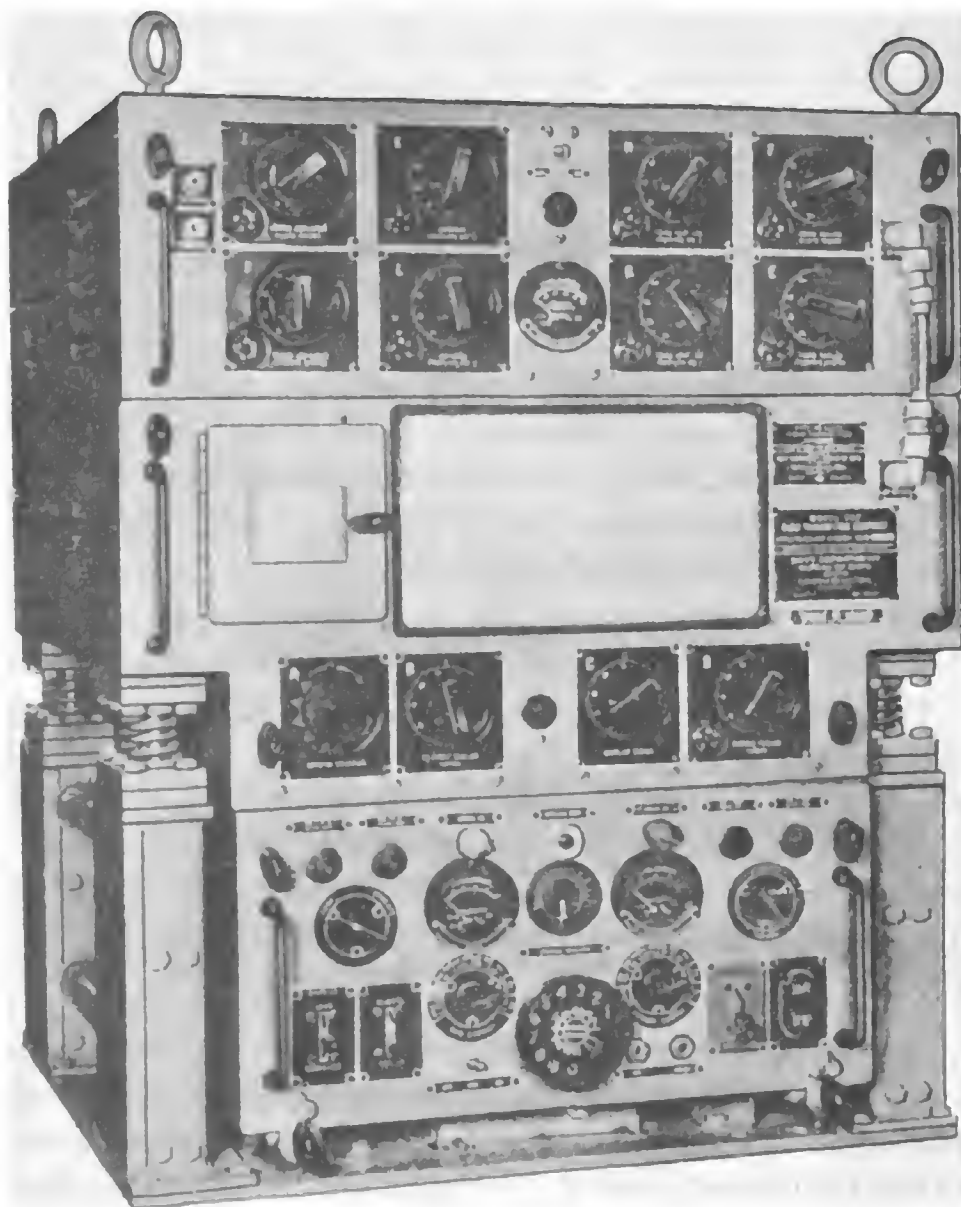


Figure 5-1.—TDZ transmitter.







gears which drive the tuning units of the low power r-f circuits and also the high power r-f circuits. Automatic change of frequency to any one of 10 predetermined frequencies is accomplished by operating a telephone dial on either the transmitter or a remote control unit. The channel frequencies need not be in any special order of succession in relation to the positions of the channel selector switch.

The mechanical portion of the system is powered by two reversible a-c series motors. The tuning heads include a system of cams which control the operation of the motors through relay switches. Pawls on the tuning head select the position at which the heads are stopped. An interlock relay deenergizes the keying circuit while the transmitter is being tuned. Another relay prevents the autotune system from being energized while the transmitter is being keyed.

Satisfactory operation depends on a clean and properly lubricated mechanism. The procedure for the inspection and lubrication of the autotune system is contained in the instruction book.

The basic advantage of the autotune system lies in its provision for automatically changing the transmission frequency in approximately 30 seconds under normal conditions. This provision prevents the loss of the radio operator's time in retuning the transmitter and makes additional weight of extra transmitters unnecessary.

A block diagram of the TDZ transmitter is shown in figure 5-2. The r-f portion of the transmitter is divided into two sections, the low power section and the high power section.

### **Low Power R-F Section**

The low power r-f section is located in the middle drawer and comprises the crystal oscillator, the crystal amplifier, the first tripler, the doubler, and the second

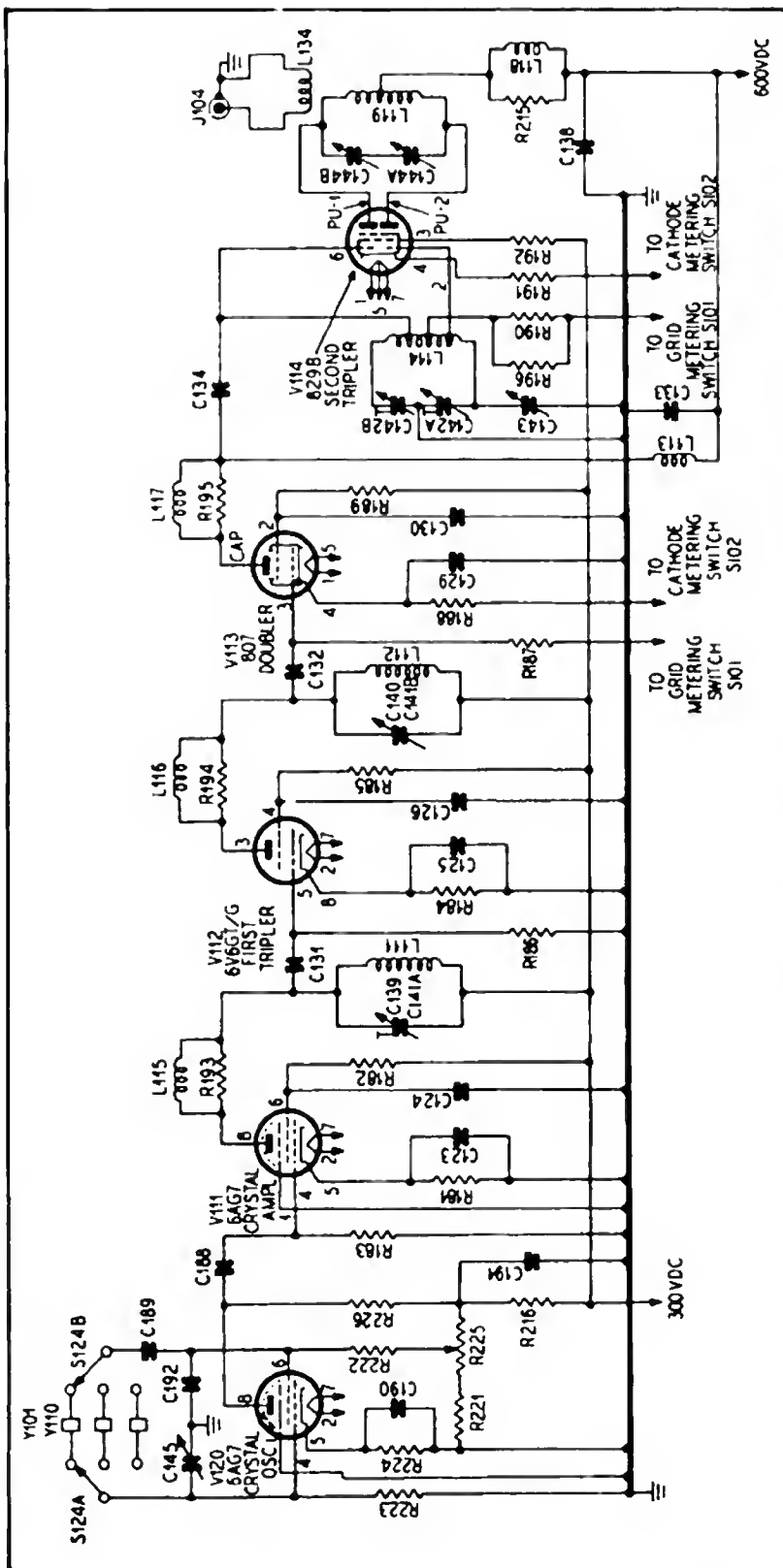


Figure 5-3.—Simplified schematic diagram of the low-power r-f section.

tripler. A simplified schematic diagram of the low power r-f section is shown in figure 5-3.

The crystal oscillator V120 is a modified electron-coupled Colpitts circuit with the crystal replacing the grid tank inductance. Capacitor C145 is a variable capacitor adjusted at the factory to compensate for differences in stray wiring capacity. Cathode bias is obtained by the voltage drop across the cathode resistors in each of the low power stages.

Screen voltage for the oscillator tube is obtained from a voltage divider across the 300-volt supply to ground. A property of the electron-coupled oscillator is that the frequency stability can be made practically independent of supply voltage variations by the proper proportioning of the plate and screen voltages. Keeping the plate voltage constant and varying the screen voltage causes the oscillator frequency to increase as the screen voltage increases. Keeping the screen voltage constant and varying the plate voltage causes the frequency to decrease as the plate voltage increases. If the plate and screen obtain their voltage from the same source and the supply voltage increases, the tendency of the plate to decrease the frequency and the screen to increase the frequency cancel each other and the frequency remains unchanged. Conversely, a decrease in supply voltage has a similar effect. The tendency of the plate to increase the frequency and the screen to decrease the frequency cancel each other.

Potentiometer R225 is adjusted at the factory to obtain optimum screen voltage and no further adjustment should be attempted. The output of the oscillator is developed across resistor R226. The oscillator plate circuit is untuned and very lightly loaded by the crystal amplifier to further insure stability. The crystal amplifier is operated as a class-C r-f amplifier. This stage isolates the oscillator from the following stages.

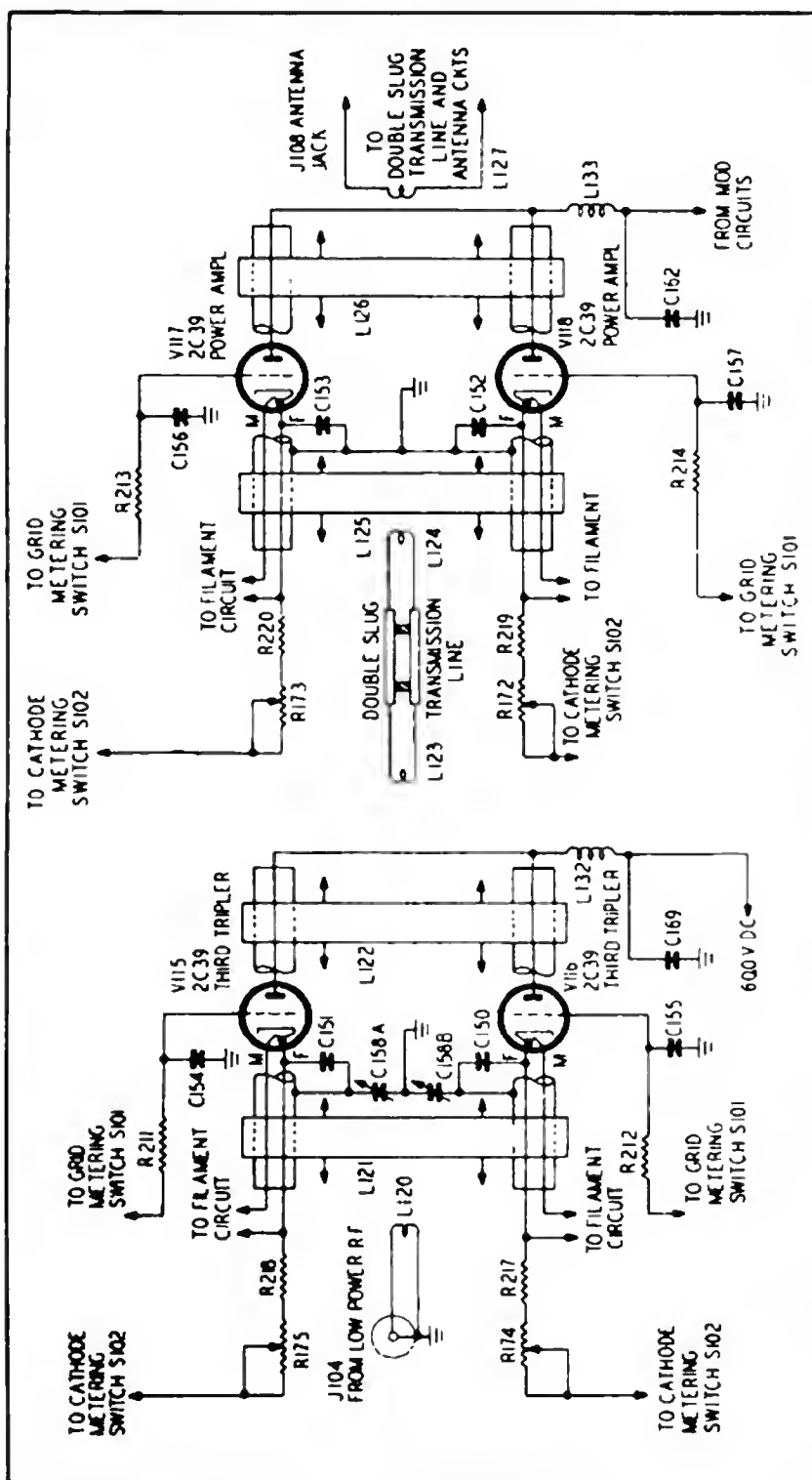
The inductor and resistor in the plate leads of the low power r-f stages act as parasitic suppressors to prevent spurious oscillations. Capacitors C141A and C141B are ganged together through the autotune system. The output of the crystal amplifier is developed across a resonant tank circuit and coupled to the first tripler grid through a capacitor.

The first tripler is a class-C frequency multiplier. The output of the first tripler is developed across the tank circuit composed of capacitor C141B and inductor L112. The grid and cathode circuits are returned to ground. Capacitor C132 couples the output of the first tripler to the grid of the doubler. The frequency doubler is operated class C. The output of the doubler is developed across inductor L113 and the shunt feed tank L114, C142A, and C142B. Capacitors C142A and C142B tune the tank circuit.

The second tripler is a class-C push-pull frequency multiplier and is the final stage of the low power r-f section. Capacitor C143 (in parallel with C142A) balances out the input capacity of the doubler and provides balanced excitation to the second tripler. Grid and cathode circuits are returned to ground through the metering circuits. Capacitors C144A and C144B tune the plate circuit. The output is coupled by inductor L134 to jack J104 on the front panel of the middle drawer.

### High Power R-F Section

Located in the top drawer is the high power r-f section. A simplified diagram of this section is shown in figure 5-4. The high power section comprises two push-pull, grounded-grid amplifiers. The grounded-grid arrangement of the third tripler and of the power amplifier eliminate the need for neutralization. The output of the low power r-f section is coupled through a short piece of coaxial cable to the cathode circuit of the third tripler.



**Figure 5-4.—Simplified schematic diagram of the high power rf section.**

The cathode circuit is maintained above ground by a tuned line. This line is resonated by capacitors C158A and C158B. The shorting bar across the line is preset to the position needed to cover the entire band and is not connected to the autotune system.

A bottom view of the third tripler assembly is shown

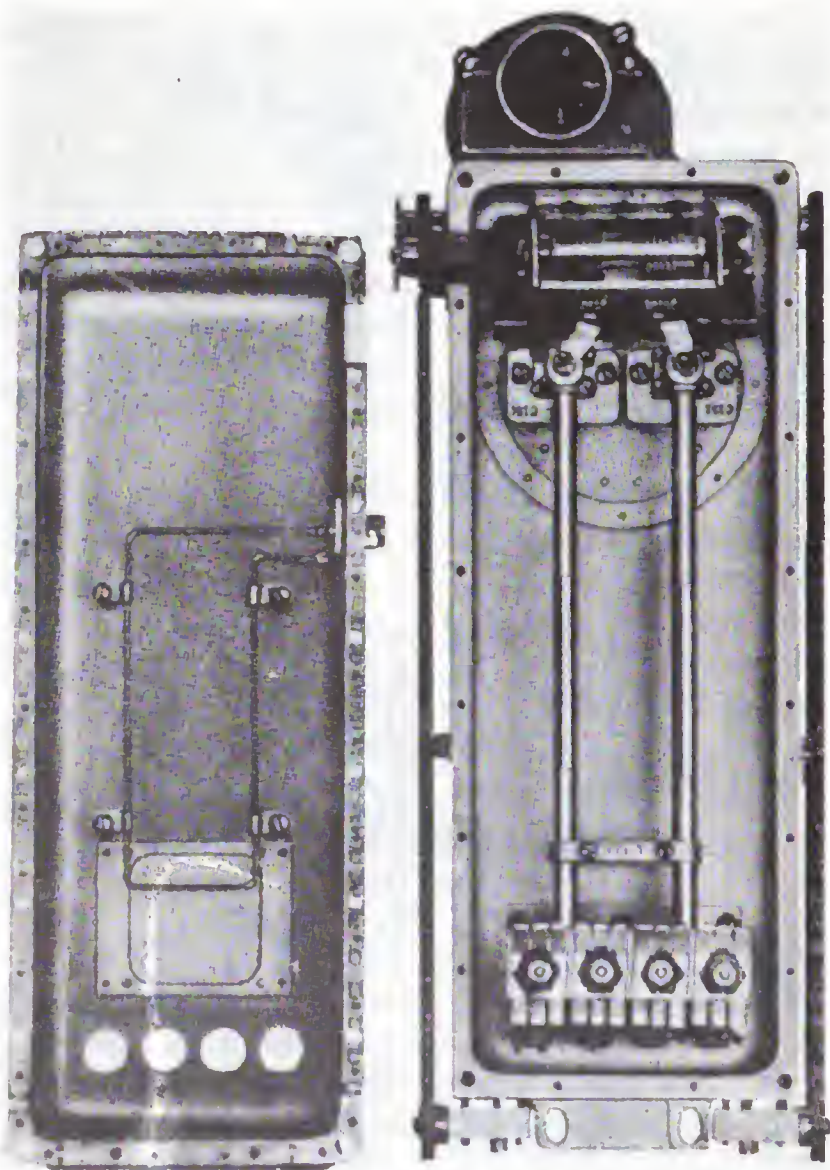


Figure 5-5.—Bottom view of the third tripler assembly.



in figure 5-5. Inside the bottom cover is inductor L120 which couples energy into the cathode circuit of the third tripler. The filament and cathode leads are placed inside the cathode tuned line. Capacitors C152 and C153 couple r-f energy from the cathode lines to the cathodes of the third tripler tubes. Capacitors C154 and C155 ground the grids of these tubes to r-f. This stage is operated class C. Grid leak bias is developed across resistors R211 and R212. Cathode bias is obtained from the voltage drop across resistors in the cathode circuit. The cathode currents of the two tubes are balanced by adjusting potentiometers R174 and R175.

The output frequency of the third tripler is high and a shorted quarter-wave stub is used as a resonant tank circuit. A quarter-wave stub is used as the plate tank in the third tripler. Inductor L123 couples the third tripler output to the first double slug transmission line.

The final amplifier assembly is similar in construction to the third tripler. This stage also uses tuned lines in the cathode and plate circuits as tuned tanks. The shorting bars across these lines are connected to the autotune system. No frequency multiplication takes place in this stage. Output of the third tripler is coupled by inductor L123, the double-slug transmission line, and inductor L124 to the cathode circuit of the final amplifier. Grid leak and cathode bias are obtained in the same manner as in the third tripler stage. Capacitors C152 and C153 couple the r-f energy from the tuned cathode lines on to the cathodes of the final amplifier tubes.

The final amplifier assembly is shown in figure 5-6. The flat single turn loop under the top cover is inductor L127. A coaxial cable connects this loop to a double-slug transmission line. The tuned lines shown in the figure are the ones in the plate circuit. The cathode lines are under the chassis and cannot be seen in the figure.

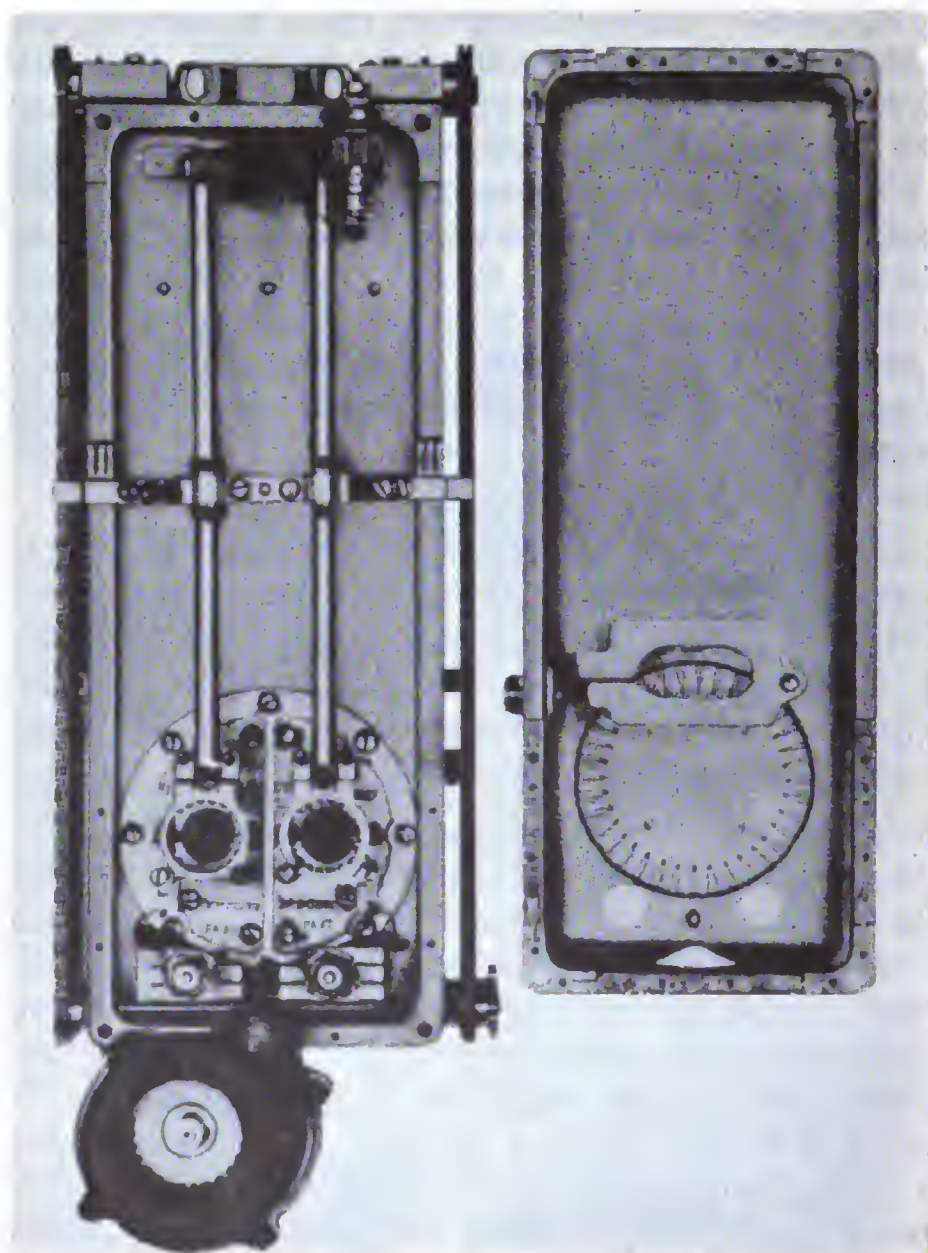


Figure 5-6.—Top view of the power amplifier assembly.

### Lighthouse Tubes

The tubes used in the third tripler and the final amplifier are called LIGHTHOUSE TUBES. Figure 5-7 shows a photograph diagram of a 2C39 lighthouse tube. In the construction of the lighthouse tube three practical fac-

tors have to be considered—(1) interelectrode capacity, (2) lead inductance, and (3) transit time.

Transit time is the time required for an electron emitted from the cathode to travel to the plate. The interelectrode capacity can be reduced by moving the elements farther apart or by reducing the size of the elements. Moving the elements farther apart would require higher plate voltages to reduce transit time. The transit time must be a small fraction of the time required for one cycle of the r-f voltage being amplified by the tube. Reducing the size of the elements has the disadvantage of reducing the power handling ability of the tube. Obviously a compromise must be made between the spacing and size of the elements and the transit time. Lead inductance is reduced by increasing the diameter of the leads.



**Figure 5-7.—2C39 lighthouse tube.**

The 2C39 lighthouse tube is used in the TDZ transmitter. The elements are assembled in parallel planes in the shape of disks brought out through the glass en-

velope. This type of construction reduces the lead inductance. On the bottom of the 2C39 are several fins which increase the surface area for radiating heat from the tube. These fins increase the power handling ability of this tube. An additional advantage of having the elements in the shape of disks is that the tube can be mounted in a coaxial cable as is sometimes done in radio and radar equipment.

### Double-Slug Transmission Lines

Maximum power is transferred from the third tripler to the final amplifier and also from the power amplifier to the antenna when the output impedance of one matches the input impedance of the other. In the TDZ these im-

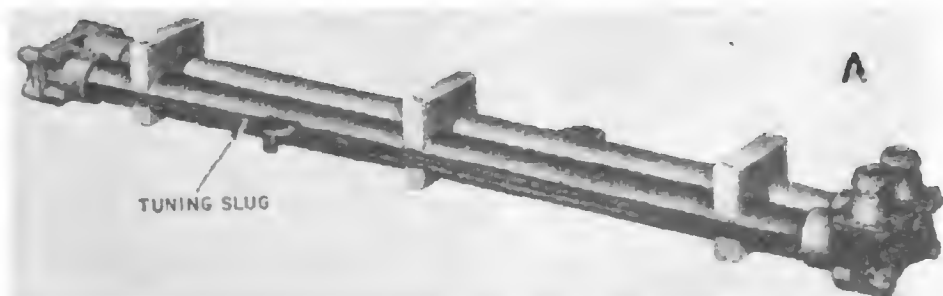


Figure 5-8.—Double-slug transmission line. A, Pictorial diagram, B, Simplified schematic diagram.

pedances are matched by using double-slug transmission lines. Two lines are used, one between the third tripler and the power amplifier and the other between the power amplifier and the antenna system.

A double-slug transmission line is shown in figure 5-8, A and B. The two slugs may be moved up and down the line independently of each other. By varying the positions of the slugs the input and output impedances of the line can be varied over a wide range.

The double-slug transmission line in the output circuit of the power amplifier is connected to the antenna trans-

fer relay and the output meter circuit through a short section of coaxial cable. A simplified schematic diagram of the output circuit is shown in figure 5-9. The antenna transfer relay K107 connects the antenna to the transmitter when the transmitter is keyed. When K107 is de-energized, the antenna is connected to an associated receiver.

A small amount of the r-f energy is coupled into the meter circuit through capacitor C181. Diode V119 rec-

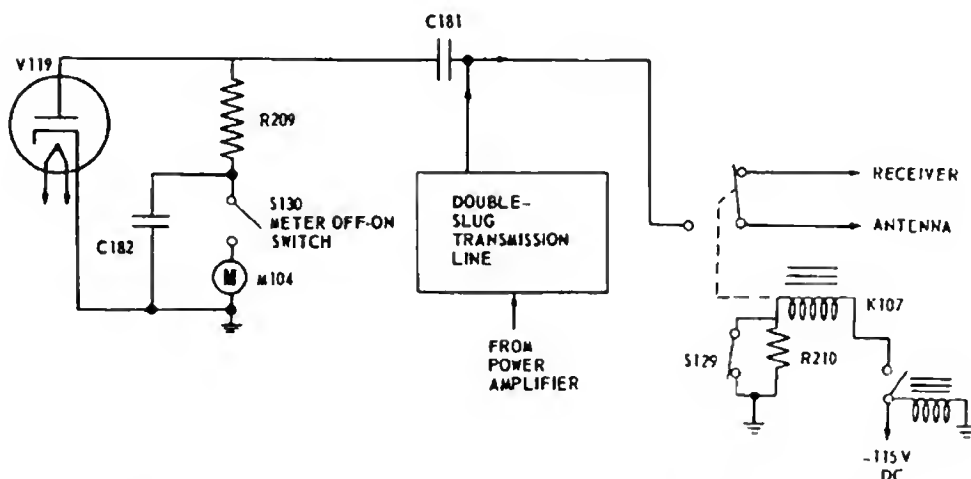
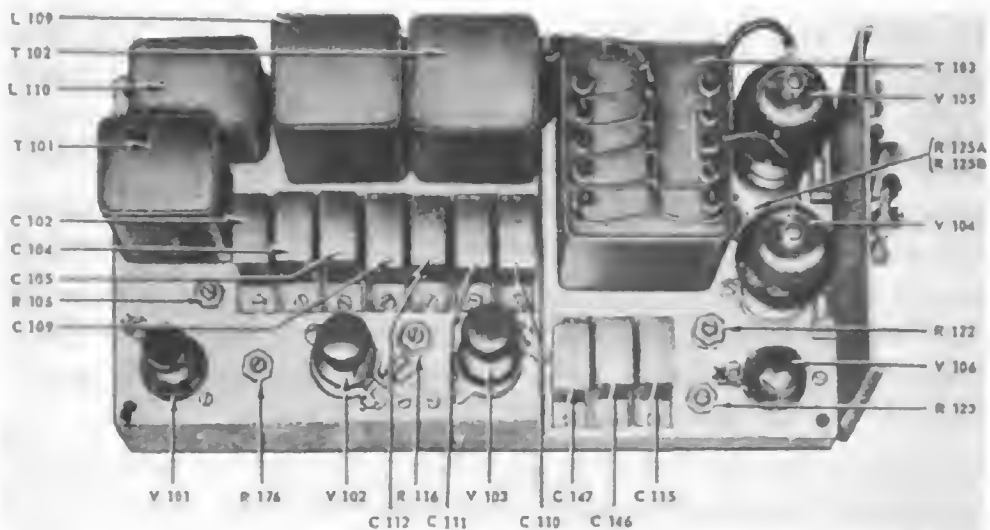


Figure 5-9.—Output meter and antenna relay circuit.

tifies the r-f voltage and the voltage appears across the diode load resistor R209. Meter M104 indicates the diode current and capacitor C182 is an r-f bypass around the meter. The meter is calibrated from 0 to 1.0 and serves only as a relative power indication.

## Audio System

The audio system supplies the modulating voltage for the final amplifier. Figure 5-10 is a pictorial diagram of the audio system. This section is made up of a first speech amplifier, second speech amplifier, audio oscillator and amplifier, and modulator stage.

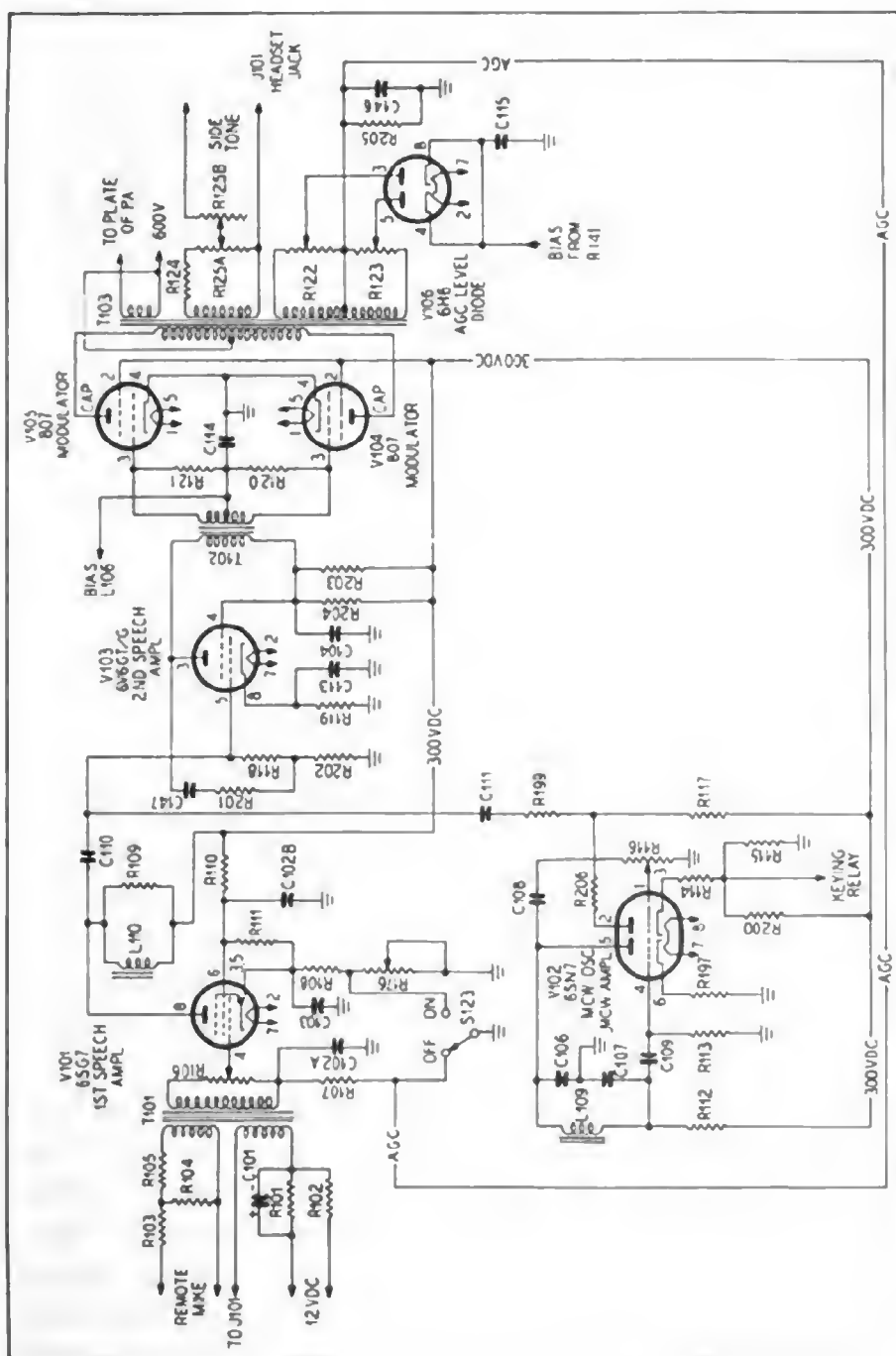


**Figure 5-10.—Pictorial diagram of the audio system.**

Figure 5-11 is a simplified schematic diagram of the audio system. The audio input from remote lines passes through a *T* pad which matches the 600-ohm line to the 1,000-ohm primary of the microphone transformer. The other primary winding matches a single button carbon microphone which may be plugged into the microphone jack.

A metallic-oxide rectifier supplies 12 volts direct current for the microphone voltage and for keying the transmitter. The microphone circuit in the TDZ transmitter is similar to that used in many Navy transmitters and will be described in detail here. A schematic diagram is shown in figure 5-12.

The CARRIER-ON RELAY K104 is energized when the push-to-talk button on the microphone, figure 5-12, A, is pressed. This relay in turn energizes the control circuit. Microphone voltage is obtained from a voltage divider network. The microphone is shown as a variable resistor in figure 5-12, B. There are two parallel paths for the d-c current, one through resistor R101, and the other through transformer T101, and the microphone. The current flowing through resistor R101 charges capacitor C101. The



**Figure 5-11.—Simplified schematic diagram of the audio and modulator circuits.**

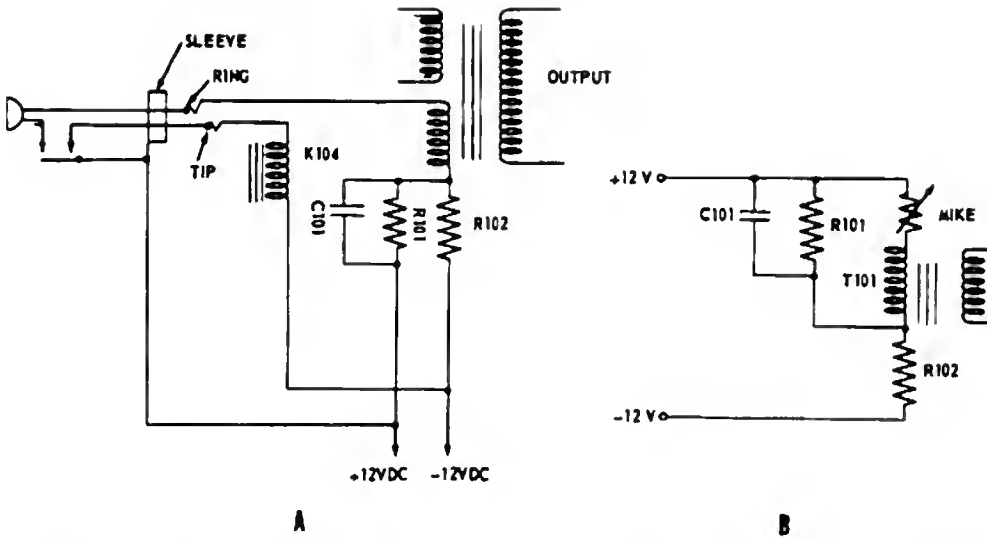


Figure 5-12.—The microphone circuit. A, schematic diagram, B, simplified schematic diagram.

capacitor acts as a battery across the microphone and transformer.

Speaking into the microphone varies its resistance. This causes the current through it to vary and induces a voltage in the output of transformer T101. However, the voltage across resistor R101 cannot change to any great extent because of the charge on the 50-microfarad capacitor C101 and the long time constant of this circuit. The individual voltages across the microphone and the transformer do vary, but their sum is always constant. The capacitor and shunt resistor R101 provide a low impedance path for the audio signal.

Resistor R101 and capacitor C101 could be omitted but that would cause the audio current to flow through the power supply in order to complete the circuit back to the other side of the microphone. This would decrease the amplitude of the audio signal in the output of T101. Further, as in the case of the TDZ and other transmitters, the power supply for the microphone is used to actuate relays. Audio voltage in the relay circuits is undesirable.

The first speech amplifier V101, figure 5-11, is a class-A voltage amplifier using a variable-mu pentode. The



input level to its grid is determined by the adjustment of potentiometer R106. Fixed bias is obtained from a voltage divider composed of resistors R111, R108, and R176 when the AGC switch is off. The output of the first speech amplifier is coupled through capacitor C110 to the grid of the second speech amplifier.

The second speech amplifier V103 operates as a class-A power amplifier and drives the modulator tubes. Resistor R201, capacitor C147, and resistor R202 comprise a degenerative feedback circuit from the plate to the grid of the second speech amplifier. The degenerative feedback appears across R202, thereby increasing the low frequency response and reducing hum generated in this stage. Transformer T102 matches the input impedance of the modulator stage to the output impedance of the second speech amplifier.

The modulator stage is a push-pull class-B power amplifier. The grids are returned through resistors R120 and R121 to the negative 30-volt d-c supply L106. The screen grids obtain voltage from the 300-volt d-c supply and the plates from the 600-volt d-c supply. T103 is the modulation transformer and has three secondary windings. One

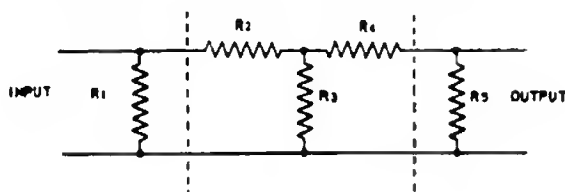


Figure 5-13.—T-pad attenuator.

winding is placed in series with the final r-f power amplifier plates, the second winding supplies side tone to a jack on the front panel of the transmitter, and the third is used to excite the automatic gain control circuit. Side tone is referred to as part of the audio-modulating voltage which is available for monitoring the speech input to the transmitter.

Resistors R124, R125A, and R125B form a *T*-pad attenuator which determines the amount of side tone. A simplified diagram of a *T* pad is shown in figure 5-13. The pad has two uses:—(1) the input resistance and the output resistance can be matched in the line, and (2) the pad can introduce a definite amount of attenuation in the line without disturbing the resistance match.

The input resistance sees a resistance equal to R2 in series with the series parallel combination of R3 in parallel with R4 and R5 in series. The load R5 looking back into the pad sees a resistance equal to R4 in series with the series parallel combination of R3 in parallel with R2 and R1 in series. By proper choice of resistors R2, R3, and R4 the input resistance and the output resistance can be matched. These circuits find extensive use in audio equipment. The equations and the mathematics connected with these circuits are too involved to be discussed here.

### Automatic Gain Control Circuit

The automatic gain control circuit limits the percentage of modulation to a maximum preset value. This circuit provides a means of automatically compensating for the fact that every operator talks into the microphone with a different intensity. The adjustment of potentiometers R122 and R123, figure 5-11, determines the amplitude of modulation voltage placed on the plates of the a-g-c level diode V106. This tube acts as a biased full-wave rectifier. The cathodes are tied together and returned to a positive bias from resistor R141 in the power supply. The amount of bias on the cathodes determines the plate voltage needed for the diode to conduct. When the voltage on the plates of the diodes exceeds the bias on the cathode, the tube conducts and rectifies the modulating voltage.

Resistor R205 and capacitor C146 filter the rectified voltage. This voltage, which is negative with respect to ground, is used as bias on the first speech amplifier. The a-g-c switch S123 in the ON position shorts out part of the

fixed bias on the first speech amplifier and removes the ground from the a-g-c line. In the OFF position the switch grounds the a-g-c line and restores normal fixed bias to the first speech amplifier by removing the short across resistor R176. Potentiometers R122 and R123 are adjusted at the factory to limit the maximum modulation to 95 percent.

### Power Supplies

The TDZ transmitter has several power supplies to supply both a-c and d-c voltages. The first one considered here is the +600-volt d-c and +300-volt d-c supply. This power supply is a duplex bridge rectifier. The voltage output of the bridge is twice that of the center tap rectifier. A simplified schematic diagram is shown in figure 5-14.

The rectifier tubes are thyratrons connected as diodes. With the polarity of the secondary of the high voltage transformer T105 as shown in the diagram, the rectified current flows through path *c*, *b*, K110, *e*, *d*, and *a*. When the polarity is reversed—that is, point *a* negative, then current flows in path *a*, *b*, K110, *e*, *d*, and *c*.

The center tap rectifier circuit utilizes two of the bridge circuit tubes, V107 and V108, together with the high voltage transformer. With the polarity of the secondary of the high voltage transformer as shown, current flows through path *c*, *b*, K110, ground, R142, R141, R140, *f*, L104, and the center tap of T105. Reversing the polarity causes the other tube to conduct and the path of the current is from *a* to *b* thence through the same patch as before. The voltage tapped off from resistor R141 is cathode bias for the a-g-c diode. Relay K110 is an overload relay.

A schematic diagram of the other two power supplies used in the TDZ is shown in figure 5-15. Both use metallic-oxide rectifiers in a bridge circuit arrangement. The output of the -115-volt supply goes to the control and autotone circuits. A -30-volt bias is also obtained from

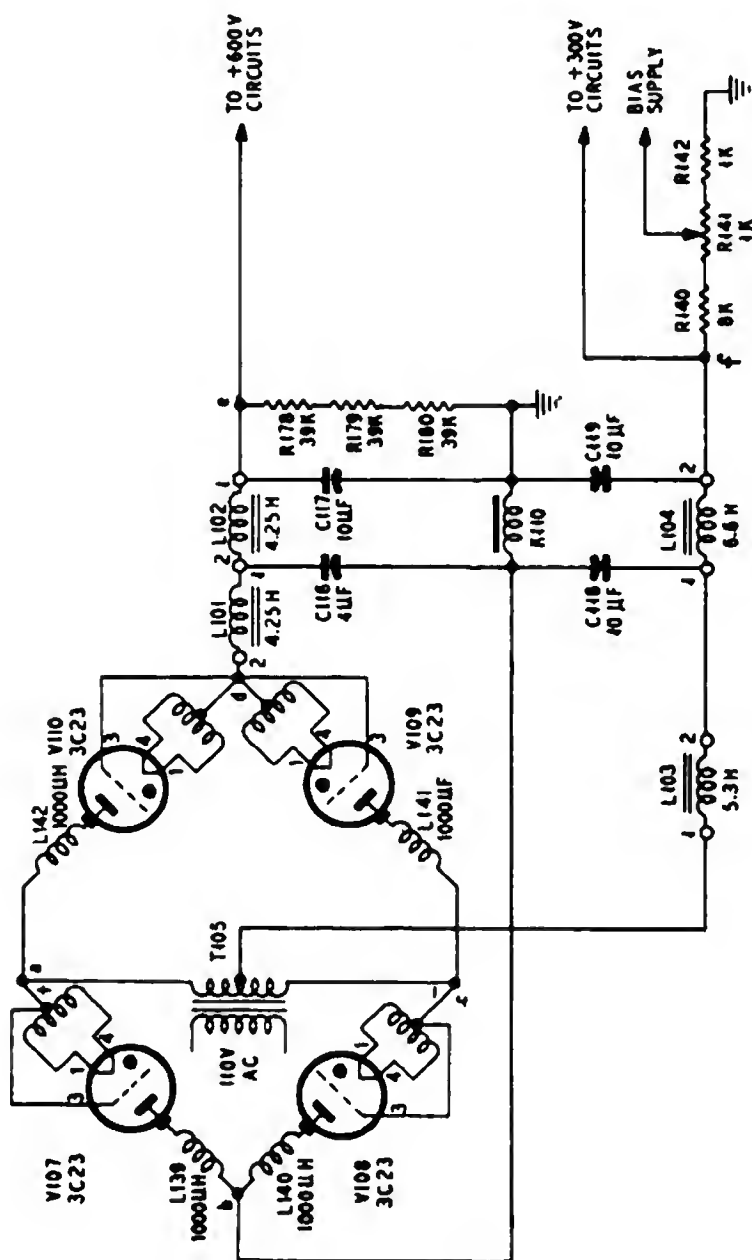


Figure 5-14.—Simplified schematic diagram of the +600-volt d-c and +300-volt d-c power supply.

this supply for the modulator tubes. Potentiometer R143 is adjusted for correct bias on the modulator tubes as given in the instruction book. Capacitor C122 and inductor L106 filter the bias voltage.

The secondary of transformer T109 is tapped so that the a-c voltage may be adjusted to compensate for aging

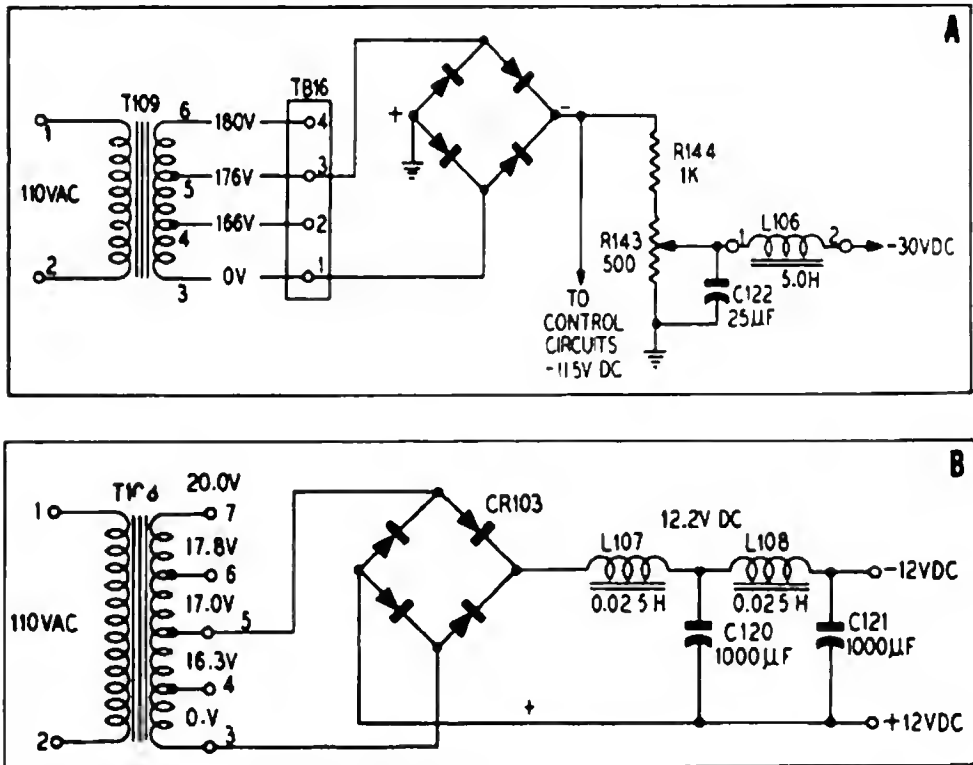


Figure 5-15.—Schematic diagrams of power supplies. A, -115-volt d-c power supply, B, 12-volt d-c power supply.

of the metallic-oxide rectifier. The metallic-oxide rectifiers are of the selenium type. As the rectifier is used its internal resistance increases and the output voltage from the rectifier decreases. To keep the output voltage to the required level, taps on the transformer are changed as the rectifier ages. Changing the taps on the transformer increases the a-c voltage to the rectifier. This increases the d-c output voltage from the rectifier and, therefore, the rectifier need not be replaced.

## QUIZ

1. (a) Can the u-h-f band be relied upon at all times to provide security beyond the horizon? (b) Why?
2. What is the range of frequencies in the u-h-f band?
3. What is superrefraction?
4. If the output frequency of the TDZ transmitter is 399.6 mc, for what frequency is the oscillator crystal cut?
5. What is the frequency range of the TDZ transmitter?
6. What types of modulation are available in the TDZ transmitter?
7. The TDZ transmitter has how many preselected channels?
8. What is the principal advantage of the autotune system as used with the TDZ transmitter?
9. What type of oscillator is used in the TDZ transmitter?
10. How do changes in plate and screen voltage affect the oscillator frequency in the TDZ transmitter?
11. Why is neutralization not necessary in the grounded grid triodes of the final amplifier?
12. (a) What type of microphone is used in the input circuit of the TDZ transmitter? (b) Why?
13. What is the purpose of the side-tone winding of the TDZ modulation transformer?
14. (a) Is the second speech amplifier of the TDZ transmitter capable of supplying power to the grids of the modulator tubes? (b) Why?
15. For what two reasons is the *T*-pad attenuator used in the TDZ side-tone circuit?
16. What precaution is taken to prevent the overmodulation of the TDZ transmitter?
17. At what percentage of modulation is the automatic gain control of the TDZ transmitter preset at the factory?
18. Which of the four tubes in the duplex bridge rectifier (figure 5-14) used in the TDZ transmitter supply power simultaneously to the 600-volt circuits and the 300-volt circuits?
19. What means are incorporated in the TDZ transmitter to compensate for the reduction in voltage caused by the aging of selenium rectifiers?

## LOW FREQUENCY COMMUNICATIONS RECEIVERS

The most popular type of receiver for receiving low frequency (l-f) signals is the tuned-radio-frequency (t-r-f) receiver. It is used in preference to the superheterodyne receiver because a t-r-f receiver for receiving l-f signals has good sensitivity and selectivity and is much simpler in design than a superheterodyne receiver.

Consider now a few of the advantages of using the superheterodyne receiver at high frequencies. First, the incoming signal is heterodyned to produce an intermediate frequency which is lower than the frequency of the incoming signal. Practically all the amplification is done in the i-f strip where the signal can be amplified efficiently. Second, the signal is amplified at a fixed frequency and a uniform amount of amplification is obtained. Since the frequency is fixed, no large ganged tuning capacitor is needed as in the t-r-f.

The choice of the intermediate frequency is more or less a compromise because a high i-f reduces the effect of image responses while a low i-f gives greater selectivity. However, the disadvantages of a high frequency t-r-f receiver are negligible in the l-f band. The frequency of operation is low enough that efficient amplification is possible using r-f amplifiers alone. From the standpoint of ease of alignment, size, sensitivity, and selectivity the t-r-f

receiver is to be preferred over a superheterodyne receiver for receiving low frequency signals.

### MODEL RBA RECEIVER

A typical low frequency Navy receiver is the model RBA shown in figure 6-1. This equipment is designed to



Figure 6-1.—RBA receiver.

receive c-w and m-c-w signals in the frequency range of 15 to 500 kilocycles. Voice reception is possible, but due to the selectivity of the r-f amplifiers and the filters in the audio amplifier section, intelligibility of speech is poor.

A block diagram of the RBA is shown in figure 6-2.



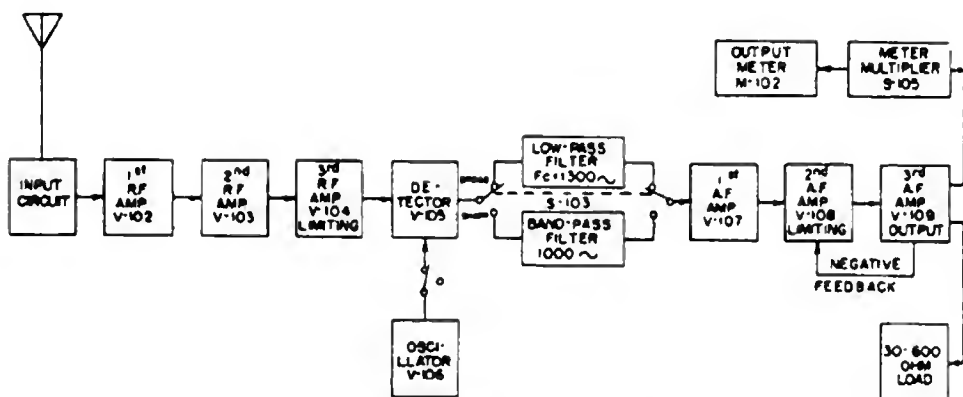


Figure 6-2.—Block diagram of the RBA receiver.

The RBA is composed of an antenna input circuit, three stages of r-f amplification, a detector, three stages of a-f amplification, and an output meter circuit. The frequency range is covered in four bands with approximately a six percent overlap between bands. Band switching is accomplished by a single control and the r-f circuits are tuned simultaneously by a ganged tuning capacitor.

The power supply of the RBA is a separate unit. It is conventional in design. A schematic diagram of the RBA receiver is shown in figure 6-3.

### Input Coupling Circuit

The input coupling circuit is the section preceding the control grid of the first r-f amplifier stage. The diagram shows the band switch in the BAND 4 position. The input coupling control S107 selects one of the coupling capacitors C141 through C145. An adjustable ANTENNA COMPENSATOR capacitor C120 is connected across the input circuit. This capacitor is adjusted to compensate for any capacity reflected in the tuned grid circuit of the first r-f amplifier by different antenna systems. By adjusting the input coupling control and the antenna compensator the input circuit can be resonated no matter what type of antenna or transmission line is used. Resistor R133 pro-

vides a leakage path to ground for static charges that might accumulate on the antenna.

The tank in the grid circuit of the first r-f amplifier is tuned by a section of the ganged main tuning capacitor C135. The antenna coil is selected by switch S106C of the ganged band switch. Switch section S106B automatically short-circuits the next lower frequency coil to prevent resonant absorption by this coil. The tap on the antenna coil selected by switch section S106A is connected to the antenna jack through the input coupling switch and one of its associated capacitors.

The four coils in the input circuit are contained in two coil assemblies, T101 and T102. Assembly T101 contains the coils for bands 1 and 2. Assembly T102 contains the coils for bands 3 and 4. Mounted on the top of each assembly is a dual trimmer capacitor consisting of two adjustable capacitors which have a common base. Similar capacitors are used with each of the other coils.

Each coil has a powdered-iron slug for adjusting the inductance of the coils. The trimmer capacitors are adjusted when the receiver is tuned to the high frequency end of the band and the iron cores are adjusted at the low frequency end to make the receiver track. On bands 1 and 2 the tuned tank circuits have resistors in series with the inductance. The resistors lower the  $Q$  of the inductor to an optimum value. Without the resistors, static and telegraphic code signals shock-excite the tuned tank into oscillation sometimes making the received signal unreadable. Resistors are not needed on bands 3 and 4.

A neon lamp V101 protects the input circuit against excessive voltage. If the voltage across the tuned input circuit exceeds 90 volts, the lamp ionizes and becomes a low impedance across the circuit. High voltage could be caused by tuning the receiver to the frequency of a nearby transmitter which is in operation.

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**WITNESSES:**

## R-F Amplifiers

The first and second r-f amplifiers are identical. Only the first one will be described here. The first r-f amplifier stage is conventional in design with its output developed across inductor L108A. The letters "A" or "B" following the symbol designations of the inductors indicate primary or secondary windings, respectively. Bias for the first and second r-f amplifiers is a combination of fixed and cathode bias. Cathode bias is obtained from the voltage drop across the cathode resistor. Fixed bias is obtained from a voltage divider across the plate supply to ground.

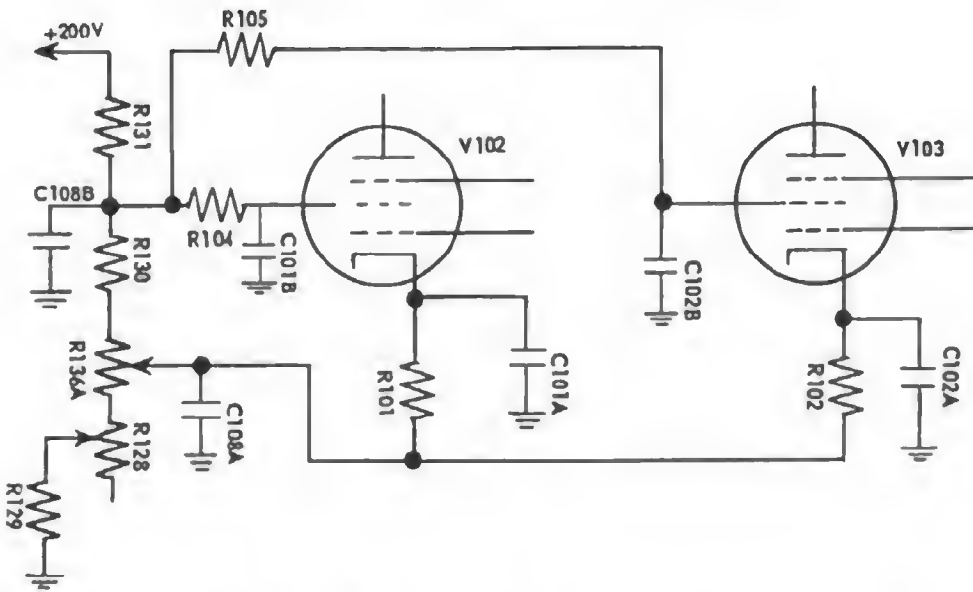


Figure 6-4.—Simplified schematic diagram of the bias circuit.

A simplified schematic diagram of the bias circuit is shown in figure 6-4. Resistors R129, R128, R136A, R130, and R131 form the voltage divider. Potentiometer R136A is part of the manual gain control. This potentiometer controls the amount of fixed bias placed on the grids of the first and second r-f amplifiers and hence controls the gain of these stages. In a t-r-f receiver the sensitivity of the receiver tends to increase as the receiver is tuned

toward the high end of the band. To compensate for the increased gain of the r-f amplifier stages, rheostat R128 automatically increases the bias on the first and second r-f stages as the receiver is tuned to higher frequencies. Rheostat R128 is geared to the tuning capacitor.

The third r-f amplifier is similar to the first two r-f amplifiers except that the plate and screen voltages for this stage are reduced to about 15 volts. The low voltages on this amplifier cause it to act as a limiter for strong signals. For weak signals it provides some amplification. The output to the detector tube is held fairly constant by the third r-f amplifier, which prevents strong signals from overloading the detector tube.

### **Detector**

The output of the third r-f amplifier is detected by V105 which operates as a plate detector. The cathode bias developed across resistor R110 is close to the amount needed to cut off V105. When a signal is placed on the grid of this tube, the signal will be rectified. As the signal swings positive, the plate current increases. As the signal swings negative, the plate current is cut off.

The output is developed across resistor R111. The audio voltage is coupled into the audio circuit by capacitor C109. Link E101, which is normally closed, is in series with the cathode of the detector tube. The link may be opened and a microammeter inserted to measure the cathode current of the detector. To reduce microphonics caused by vibration of the detector tube, its socket is cushion-mounted.

### **C-W Oscillator**

For the reception of c-w signals the incoming signal is mixed with the output of an oscillator. The oscillator V106 is an electron-coupled Hartley oscillator operating at 1000 cycles above the incoming signal frequency. A section of

the ganged tuning capacitor, C135E, varies the frequency of the c-w oscillator. The band switch position determines the oscillator coil selected.

The oscillator is placed in operation by switch S102 which applies plate voltage to the oscillator tube. The output of the oscillator is coupled to the plate of the third r-f amplifier. The incoming signal and the oscillator signal are coupled through the r-f transformer to the grid circuit of the detector tube. A received signal beats with the oscillator signal in the detector to produce an audio signal in the detector output.

### Audio Filter

The audio output of the detector is coupled through capacitor C109 to one of the audio filters. With the BROAD-SHARP switch S103 in the BROAD position a low pass filter is inserted in series with the detector output and the control grid of the first a-f amplifier tube. This filter attenuates audio frequencies above 1300 cycles. When the broad-sharp switch is in the SHARP position, a band-pass filter is inserted in series with the grid of the first a-f amplifier. This filter passes only audio frequencies between 850 and 1150 cycles.

A *T* pad composed of resistors R112, R113, and R122 equalizes the effective insertion loss of the two filters at the center of the acceptance band (1000 cycles) of the band-pass filter. The filters are terminated in their characteristic impedances by resistors R136B and R114 connected in series. Potentiometer R136B is the audio gain control.

### Audio Amplifiers

The first and second audio amplifiers are conventional *R-C* coupled amplifiers when the OUTPUT LIMITER switch S104 is in the OFF position. When the output limiter

switch is ON, the second a-f amplifier V108 becomes a limiter. Plate and screen voltage for the second a-f amplifier is obtained directly from the 200-volt d-c output of the power supply, when switch S104 is OFF. If switch S104 is placed in the ON position, the plate voltage and the screen voltage for the second a-f amplifier are obtained from a voltage divider composed of resistor R123 and potentiometer R137. The output of the second a-f amplifier depends on the plate and screen voltage. By properly adjusting potentiometer R137, the output of the receiver can be held constant.

The third audio amplifier is the output stage. It is a conventional audio power amplifier with inverse feedback. Capacitor C136 connected across the primary of the output transformer prevents shock excitation of the circuit, when static or c-w signals are received. Transformer T111 has two secondary windings. One winding is for the output meter circuit and the other winding connects to headphones. When a load of 30 ohms is connected across the headphone winding, the primary winding matches the plate impedance of the output tube.

Chokes and capacitors in the headphone circuit are filters that prevent any stray r-f from entering the receiver through the headphone cord. The headphone winding is connected to the output receptacle mounted on the rear of the chassis and also to the headphone jack on the front panel of the receiver.

### Output Meter Circuit

The output meter is connected to a secondary winding of the output transformer. The connection to the 5000-ohm output meter is made through switch S105 and the meter multiplier resistors. The meter winding has more turns than the headphone winding so that the meter can measure smaller values of output power than would be possible if it were connected directly across the headphone



winding. Switch S105, marked "ADD-DB" on the front panel of the receiver, together with its associated resistors form an adjustable attenuating network or *L* pad. The circuit is so arranged that regardless of the position of S105 the load across the meter winding remains at 5000 ohms.

A simplified schematic diagram of the meter circuit is shown in figure 6-5. Values of the meter resistance and

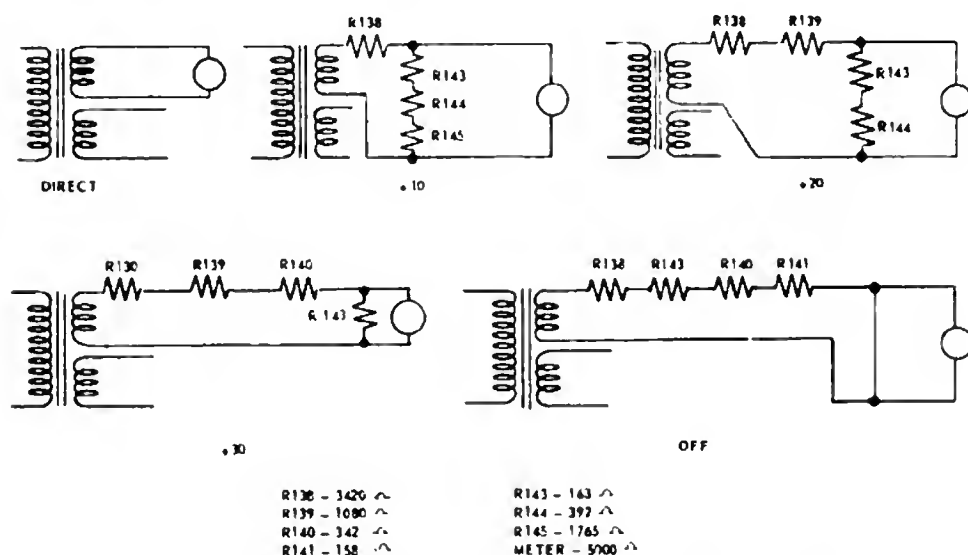


Figure 6-5.—Simplified schematic diagram of the output meter circuit.

of the different resistors are shown in the diagram. With Ohm's law it can be shown that, regardless of the position of S105, the load across the meter winding is always 5000 ohms. Meter deflection is proportional to the voltage across the headphone load. The power indicated by the meter is correct only when a 600-ohm resistive load is connected across the headphone winding. As a safeguard against damage to the meter, a spring returns switch S105 from the direct position to the +10 db position, when the switch is released. The meter should be switched off when it is not being used.

## Negative Feedback Circuits

Negative feedback circuits are incorporated in the RBA receiver to prevent variations in the output level when headphones are inserted or removed from the output line. Any number of headphones, from 1 to 20, may be used simultaneously without changing the output level appreciably.

Two feedback circuits are used to obtain a substantially constant output voltage as the number of headphones across the output varies. One feedback circuit is connected from the plate of V109 through capacitor C105B and resistor R150 to the grid of V109. The other is connected from the plate of V109 through capacitor C105A and resistor R152 to the cathode of V108. When there is no load across the output winding, a maximum amount of negative feedback is applied through these circuits and the gain of the audio amplifiers is reduced. If a load is placed across the output winding, the output voltage tends to decrease. This decreases the amount of negative feedback and increases the gain of the audio amplifiers. The reverse situation occurs when the load is decreased—that is, the output voltage and the negative feedback increase and the gain of the audio amplifiers is reduced.

## LONG-WAVE RECEIVING ANTENNAS

The wavelength of a signal is inversely proportional to its frequency. Frequencies below 500 kc require large antenna systems. At high frequencies it is possible to build antennas which are directional and small in size. A frequency of 30 kc has a wavelength of approximately 32,800 feet while a frequency of 30 Mc has a wavelength of only about 32.8 feet.

Long-wave antennas erected aboard ships generally consist of a whip or a piece of wire. The receiver usually has a circuit incorporated in it to match the input circuit

to the antenna. On shore stations, where a large amount of space is available, directional antennas can be erected. A disadvantage of any long-wave antenna system which is directional is that it is useful for point-to-point operation only, whereas, at higher frequencies, the antenna can be constructed so that it can be rotated.

### Beverage Antenna

A type of directional long-wave receiving antenna is the BEVERAGE ANTENNA (figure 6-6). This antenna is

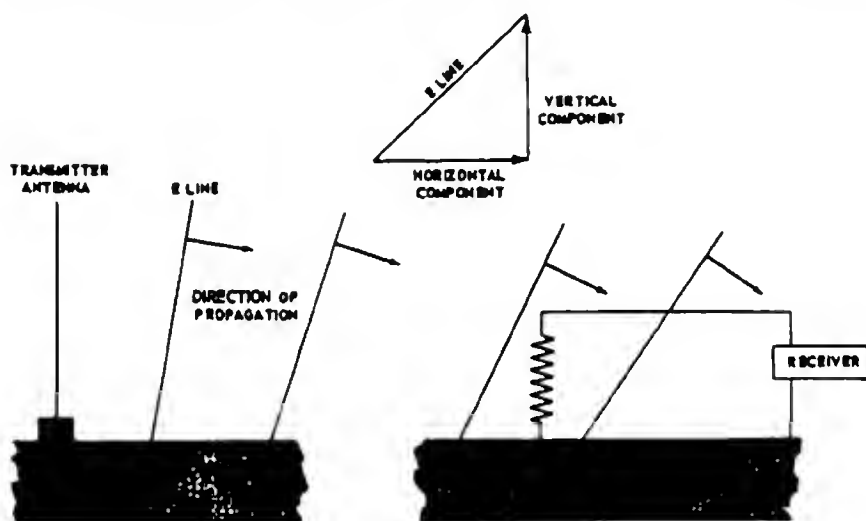


Figure 6-6.—Pictorial diagram of a Beverage antenna.

simply a single long wire. It is usually one-half to several wavelengths long and is erected 10 or 20 feet above the ground. The wire is pointed toward the transmitting station. A resistance equal to the characteristic impedance of the antenna is connected from the end closest the transmitting station to ground. The antenna may be considered as a one-wire transmission line with a ground return.

The Beverage antenna has good horizontal directivity. Using several of these antennas in a simple array increases the directivity. Since the antenna is nonresonant, it can be used for the reception of several different fre-

quencies without too much loss in directivity. A Beverage antenna is suitable only for reception. If it is used as a transmitting antenna, the ground losses are high and the antenna is not very efficient.

The voltage induced into the antenna is delivered to the receiver at the opposite end from the terminating resistor. When a wavefront is traveling as shown in figure 6-6, the voltages induced in different parts of the antenna add, because they are in phase with the radio wave. If the wavefront were traveling in the opposite direction, the induced voltages would still be in phase, but they would be absorbed by the terminating resistor and have no effect on the receiver. Wavefronts arriving at the sides of the antenna have no effect on the receiver. This is true because, even though the induced voltages may be in phase at their points of origin, they are induced at different points and therefore, effectively cancel one another.

In figure 6-6 the transmitting antenna radiates a vertically polarized wavefront. As the wavefront travels toward the receiving antenna, it is tilted due to the absorption of the earth and changes in the propagation velocity. When the wavefront arrives at the receiving antenna, the E lines are no longer vertical. Instead they have both a vertical and a horizontal component. The horizontal component causes the voltage to be induced in the receiving antenna. Therefore, the more the wavefront is tilted, the greater the horizontal component and the greater the voltage induced in the antenna.

## QUIZ

1. In what frequency band is a t-r-f receiver to be preferred over a superheterodyne receiver?
2. What is the basic difference between t-r-f and superheterodyne receivers?
3. What is the purpose of resistor R133 in the input circuit of the RBA receiver?
4. What is the function of the neon lamp, V101 (figure 6-3), in the RBA receiver?
5. By what methods is gain control accomplished in the RBA receiver?
6. The sensitivity of a t-r-f receiver tends to increase as the receiver is tuned to the high end of the band. How is this increased sensitivity controlled in the RBA receiver?
7. What is the value of the plate and screen voltages on the third r-f stage in the RBA receiver?
8. Give the reason for using the value of plate and screen voltages on the third r-f stage in the RBA receiver.
9. How does the RBA receiver produce audio signals in the reception of c-w signals?
10. What does each position of the "Broad-Sharp switch," S103, do to the audio signal in the audio-filter section?
11. How does the second audio amplifier stage become an output limiter?
12. What is the purpose of the chokes and capacitors in the head-phone circuit of the RBA receiver?
13. How does negative feedback in the RBA receiver operate to give practically constant output level with a varying amount of output load?
14. What is the wavelength in feet of a radio wave whose frequency is 150 kc?
15. What is the advantage of using high frequency in connection with directional antennas?
16. (a) Is the Beverage antenna suitable to use as a transmitting antenna? (b) Why?
17. How can the directivity of the Beverage antenna be increased?



## **MEDIUM- AND HIGH-FREQUENCY COMMUNICATION RECEIVERS AND ANTENNA SYSTEMS**

### **HIGH-FREQUENCY PROPAGATION**

The high-frequency band (h-f) extends from 3 to 30 megacycles. The ground wave at the low end of the h-f band may be used for communications up to about 30 miles. At distances greater than this, the ground wave is practically nonexistent. As the frequency is raised toward the high end of the band, the ground-wave range decreases. Little advantage is gained by elevating the antenna to obtain a direct wave because of the interference between the direct wave and the ground reflected wave. The height of the antenna is important, however, for sky-wave transmission of h-f waves.

The range of sky-wave transmission is largely determined by the condition of the ionosphere. During the night, frequencies greater than 8 megacycles often penetrate the ionosphere at all angles of radiation. These frequencies can not be used for long range communications. However, during the day, frequencies between 15 and 30 megacycles may be used for long range communications and the frequencies between 5 and 10 megacycles for communications up to several hundred miles.

The upper portion of the medium-frequency band and all of the high-frequency band are generally used for long range communications.

## ANTENNA SYSTEMS

The antenna systems generally used aboard ship for receiving signals in the m-f and h-f bands are either a whip or a long wire. At the upper end of the h-f band a directive antenna of reasonable size could be constructed to obtain the advantage of power gain and directivity. However, directive antennas aboard ship are of doubtful use. Since ships are on constantly changing courses, a receiving ship would not know in which direction to train the antenna to receive a signal from a given ship.

For point-to-point communications the directive antenna is very desirable. Two of the principal advantages of using a directive antenna are (1) the power gain and directivity obtained for transmitting and (2) the increased signal-to-noise ratio for receiving.

One type of directive antenna is the V antenna shown in figure 7-1. This antenna is relatively easy to construct and has fairly high gain. The antenna shown in figure 7-1,A, is the resonant type. When fed with tuned feeders, it will operate on several harmonically related bands. The resonant V antenna has a bidirectional pattern. Several factors determine the directivity of the V antenna—the height above the ground, the angle enclosed between the legs, and the length of the legs. The angle of radiation is determined to some extent by the angle between the antenna and the horizontal.

Figure 7-1,B, shows the nonresonant V antenna. The legs of this type terminate in their characteristic impedances and the antenna has a unidirectional pattern. Each of the legs is terminated in a resistance of from 400 to 800 ohms. The resistors are adjusted for minimum



standing waves. Since the antenna is nonresonant, it will operate over a relatively wide range of frequencies without adjustment as compared to the resonant V antenna.

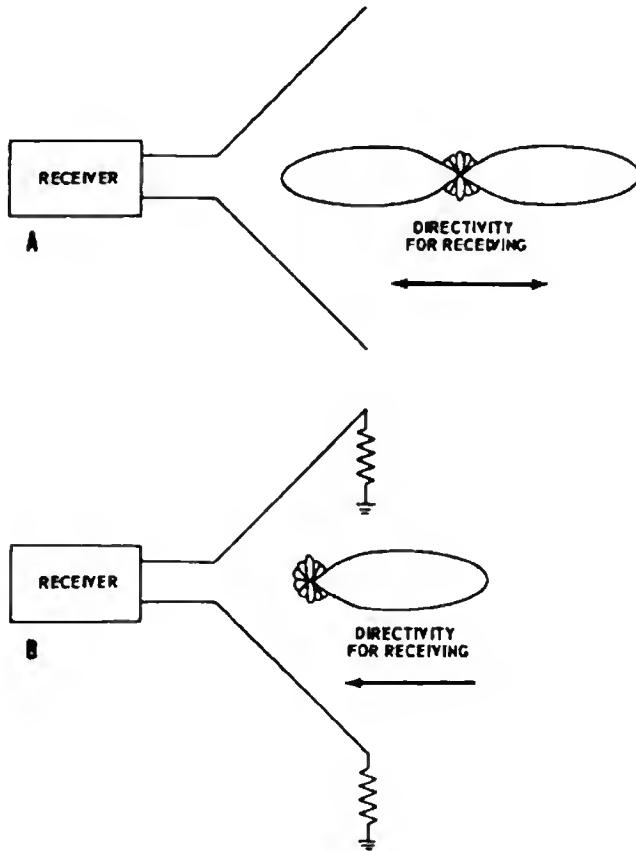


Figure 7-1.—V antenna, A, Resonant, B, nonresonant.

Two or more V antennas may be stacked to form an array to get additional gain and directivity. However, with this scheme the antenna must be resonant. A more elaborate type of V antenna is the RHOMBIC ANTENNA shown in figure 7-2. This antenna has excellent directivity, high gain, and, since it is nonresonant, will operate over a wide band of frequencies without adjustment. The rhombic antenna has a unidirectional pattern and is terminated in its characteristic impedance which is about

800 ohms. This antenna is generally designed to operate at frequencies between 5 and 30 megacycles. The legs are usually about three wavelengths long.

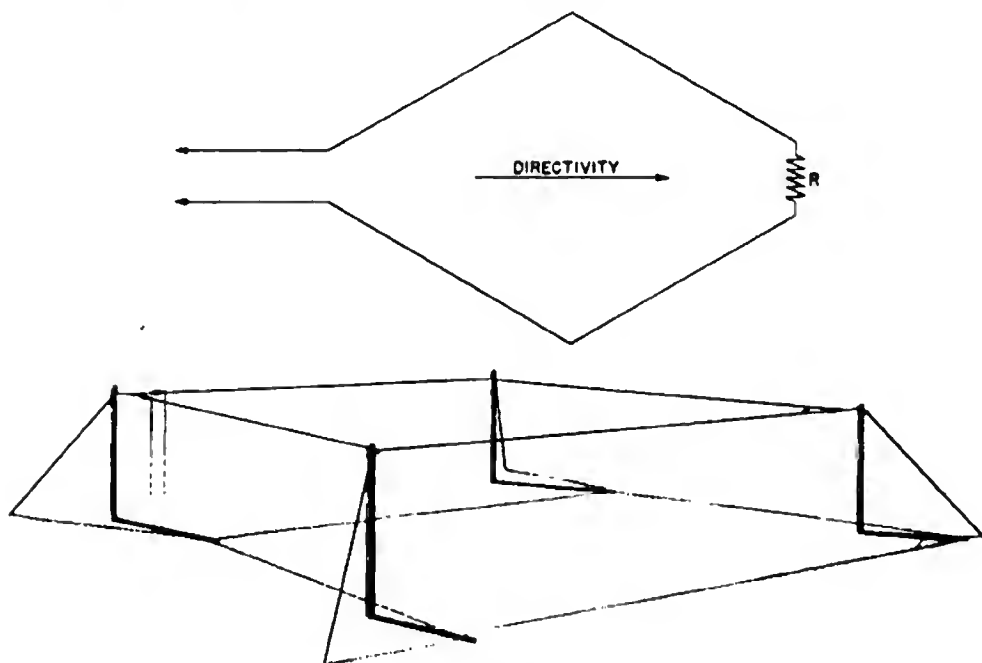


Figure 7-2.—Rhombic antenna.

## MODEL RBB AND RBC RECEIVERS

The basic superheterodyne receiver is discussed in *Electronics Technician 3*. The purpose of this chapter is to point out and explain some of the refinements of the basic receiver. The RBB and RBC together with the RBA receiver make up a series of receivers which cover the frequency spectrum from 15 kilocycles to 27 megacycles. The RBB and RBC receivers are similar in design and construction. Both use an external power supply.

A photograph of the RBB receiver appears in figure 7-3.

Both receivers are divided into two sub-assemblies—the preselector and the i-f/a-f section. They are bolted together and housed in the same cabinet. The preselector



**Figure 7-3.—Navy Model RBB receiver.**

contains the antenna circuit, local oscillator, mixer, and r-f amplifiers. The i-f/a-f section includes the i-f amplifiers, c-w oscillator, silencer, noise limiter, second detector, and audio amplifiers. The i-f/a-f sections in the RBB and RBC receivers are identical with the exception of the audio band-pass filters.

### **Antenna Input Circuit**

The antenna input circuit can be set up so that the receiver may be used with several different antenna systems. The antenna jack on the rear of the receiver is connected to a system of links that may be positioned to match the input to different antennas or to different coaxial lines. Two of the possible arrangements obtained by different link connections are (1) operation of one or more RBB or RBC receivers from the same antenna or transmission line and (2) operation of an RBB receiver with other low-frequency receivers from a common antenna. The link arrangements for the RBB and RBC are similar.

Referring to the schematic diagram of the preselector unit of the RBB shown in figure 7-4 notice that, depending on the positions of the links, the antenna may be connected to either of two antenna coupling coils. The input coupling coils are designed to resonate with the antenna below the low frequency limit of the associated band and to match the receiver input to antenna circuit impedances varying from 300 ohms at the high end of the receiver range to about 1500 ohms at the low end.

The antenna coupling coils are magnetically coupled to a tuned circuit composed of capacitor C149A and the coil selected by band switch S102. This tuned circuit is in turn magnetically coupled to another tuned grid input circuit of the first r-f amplifier V101. Capacitor C149B tunes this resonant tank circuit. The extra tuned tank circuit increases the selectivity of the receiver. The voltage limiter V105 is a small gas tube which ionizes in case excessive voltage is developed across the first tuned tank circuit. This protects the tuned circuit against damage that might be caused by energy from nearby transmitting antennas. Capacitor C128 is the ANTENNA COMPENSATOR control and is used to resonate the first tuned circuit with the antenna.

### R-F Amplifiers

A-v-c voltage is applied to the first r-f amplifier through resistor R109. Capacitors C149A, B, C, D, and E are ganged on a common shaft. These capacitors tune the receiver. The r-f amplifiers are conventional in design. An i-f wave trap in the screen circuit of the first r-f amplifier blocks interfering i-f signals and is especially useful in blocking interference from low-frequency transmitters located close by. If the trap were not present these signals would go straight through the i-f amplifiers. The trap is parallel resonant to the i-f and causes degenerative feedback which tends to cancel the unwanted

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signal. The action is similar to that of an unbypassed cathode resistor except that the resonant tank increases the amount of degenerative feedback and makes it frequency sensitive.

### Local Oscillator

The local oscillator of the RBB receiver is specially designed for good stability under adverse operating conditions. Varying humidity, temperature, supply voltage, and vibration have little effect on the oscillator frequency. The oscillator is an electron-coupled oscillator. Different frequency bands are selected with switch S105. A section of the tuning capacitor, C149E, tunes the oscillator.

To insure stability the components have low temperature coefficients of expansion and the plate and screen voltages are obtained from a voltage regulator in the power supply. Stability is further improved by a current regulator in the filament circuit. Potentiometer R116 is adjusted to a value such that any variation in the filament supply voltage will not affect the filament voltage.

Capacitors C145, C146, C147, and C148 are trimmer capacitors. Capacitors C101, C102, C103, and C104 are negative temperature coefficient capacitors. As the temperature of the tuning capacitor and the trimmer capacitors increases, their capacity tends to increase. The increased capacity is compensated for by the negative temperature coefficient capacitors which decrease in capacity as temperature increases. Capacitors C108, C109, C110, and C111 are padding capacitors connected in series with the tuning capacitors and the trimmers to reduce their capacity so that the oscillator will track 400 kc above the incoming frequency.

The output of the local oscillator is capacitively coupled to the cathode of the mixer tube. The incoming signal is coupled from the second r-f amplifier to the control grid of the mixer tube. The two frequencies heterodyne and

the difference frequency, 400 kc, is amplified by the i-f amplifiers.

### I-F/A-F Section

The i-f/a-f section is the same for both the RBB and RBC receivers with the exception of the audio filters. Five different types of reception are possible by positioning the RECEPTION TRANSFER switch. Figure 7-5 is a simplified schematic diagram of the i-f stages when the reception transfer switch is in the MOD position. The i-f amplifiers are conventional in design. The i-f transformers are shown on the diagram as having only one secondary winding. Actually each transformer has three secondary windings. Only one of these is used at a time. Each secondary has a different amount of coupling with respect to the primary. The winding selected depends on the position of the RADIO SELECTIVITY switch. Changing the position of this switch changes the selectivity of the receiver by altering the coupling between the primary and secondary windings of the i-f transformers.

Potentiometer R361A is in series with the i-f amplifier cathodes and controls the gain of these stages by varying the cathode bias. When the reception transfer switch is in the MOD-AVC position, the manual gain controls are removed from the circuit. The a-v-c voltage then controls the gain of the r-f amplifiers and the first two i-f amplifiers. A-v-c voltage is not applied to the third i-f amplifier.

A simplified schematic diagram of the i-f/a-f unit when the reception transfer switch is in the MOD-AVC position is shown in figure 7-6. The output of the third i-f amplifier is applied to the detector. The audio output of the detector appears across the diode load resistors R347 and R348. Only half of the audio voltage is coupled to the grid of the first audio amplifier. Potentiometer R363A is the audio gain control and is labeled "Output Level" on the front panel of the receiver.



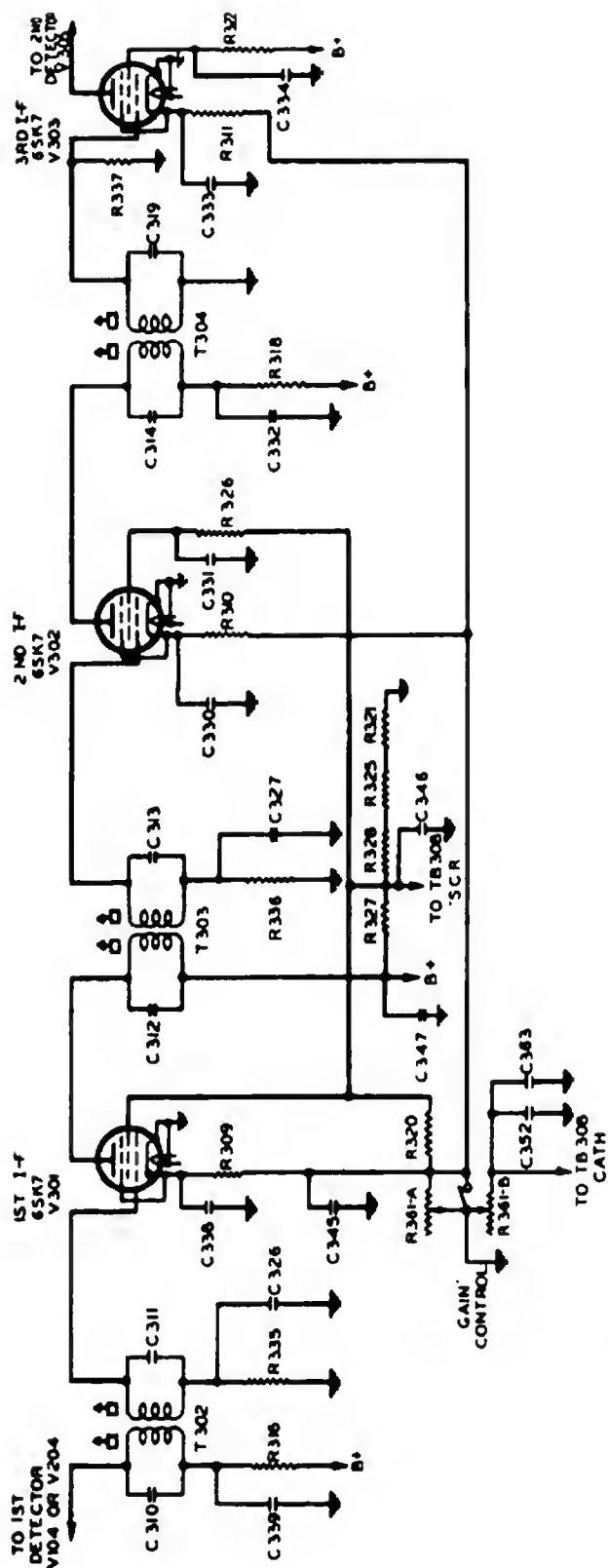
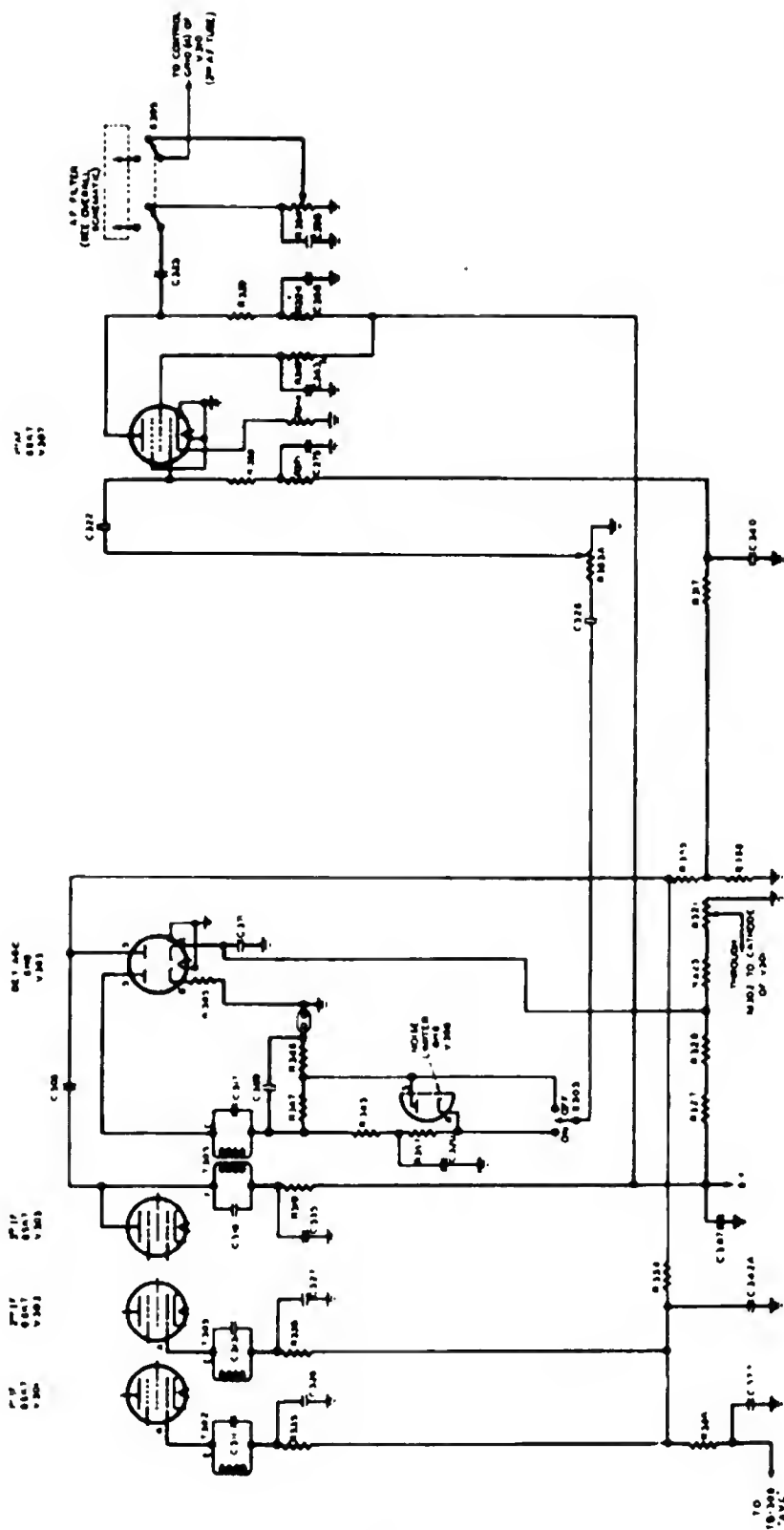


Figure 7-5.—Simplified schematic diagram of the i-f amplifier stages with the reception transfer switch in the MOD position



**Figure 7-6.—Simplified schematic diagram of the i-f, a-f section with the reception transfer switch in the MOD-AVC position.**

## Noise Limiter

A noise limiter prevents impulse noise from going through the audio amplifiers. When strong impulses of noise are received, the noise limiter acts as an open switch between the detector and the first audio amplifier. The noise limiter diode normally acts as a low resistance in series with the detector output and the audio amplifier input. With the noise limiter switch S303 ON and a normal signal being detected, the output appears across the two diode load resistors which are of equal value. The detector output is essentially a d-c voltage varying at an audio rate. Due to the current flow through the detector, the end of resistor R347 connected to resistor R345 is negative with respect to ground.

The full negative output voltage of the detector is coupled to the cathode of the noise limiter while the plate of the noise limiter is somewhat less negative. In this condition the noise limiter diode conducts and the audio signal appears on the grid of the first audio amplifier. Now, if a pulse of noise is detected by the detector, it will appear as a sharp spike of voltage across the detector load and resistor R345. The pulse voltage across resistor R345 makes the plate of V306 momentarily negative with respect to its cathode during the time required to charge C320 through R345. The noise limiter diode ceases to conduct during this interval and the noise pulse is bypassed to ground through C320.

Delayed a-v-c voltage is obtained from the second half of V305. The circuit is designed so that no a-v-c voltage is applied to the r-f or i-f stages when weak signals are being received. A positive bias is connected to the cathode of the a-v-c diode by means of the bleeder network R327, R328, R325 and R321. If the diode is to conduct and supply a-v-c voltage, its plate potential must overcome this bias on the cathode. The plate voltage is part of the i-f signal voltage coupled through capacitor C306.

For weak signals this voltage is small and the diode does not conduct. When a voltage sufficient to overcome the bias on the cathode is coupled onto the plate, the diode conducts and a voltage appears across resistors R355 and R338. Capacitors C342A and resistor R354 filter this voltage.

The time constant of the filter is long enough to remove the audio variations from the a-v-c voltage and short enough to allow the a-v-c voltage to vary with slow fading of the received signal. The a-v-c voltage developed across R338 is fed to the grid of the first audio amplifier to control the gain of this stage.

### Silencer

A simplified schematic diagram of the i-f/a-f section with the reception transfer switch in the MOD-AVC-SIL position is shown in figure 7-7. The silencer circuit cuts off the receiver output when the input level of the signal falls below a predetermined level. The point at which the silencer circuit cuts off the receiver output is determined by adjusting the silencer control R369 on the front panel of the receiver.

The full output of the detector is applied to the grid of silencer amplifier V308 through resistor R358. Since the amplitude of this voltage depends on the strength of the received signal, the bias on the silencer amplifier also depends on the strength of the received signal. Therefore the plate current and plate voltage also depend on the strength of the received signal. The bias from the detector is zero, when no signal is being received. The cathode of the silencer diode V309 is biased by a positive voltage obtained from a voltage divider, R369 and R334. The plate voltage of this diode depends on the plate voltage of the silencer amplifier V308.

Screen voltage for the silencer amplifier is obtained from the silencer control potentiometer R369. Increasing



the screen voltage increases the plate current. This in turn decreases the plate voltage on the silencer amplifier and the silencer diode. When a signal is received, the detector output biases the silencer amplifier causing a decrease in plate current and an increase in plate voltage. If the signal is strong enough, the plate voltage on the silencer diode will be sufficient for it to conduct and pass the signal to the first audio amplifier.

Adjusting potentiometer R369 determines the amplitude of received signals below which the silencer diode will not conduct and no signal will appear at the output. The silencer grid will not receive impulse noises even though they are considerably above the predetermined level at which the noise limiter functions because of the long time constant of resistor-capacitor combinations R358-C372 and R351-C373A and B. The silencer circuit may be adjusted to operate with an input signal in the range of 5 to 10,000 microvolts with the silencer control.

### **Input Meter**

A simplified diagram of the input meter circuit is shown in figure 7-8. Since a-v-c voltage is necessary for this circuit to operate, an indication will be available only when the reception transfer switch is in the MOD-AVC or the MOD-AVC-SIL positions. When no signal is being received, no a-v-c voltage is applied to the first i-f amplifier. The meter circuit is similar to a simple bridge arrangement. Resistor R321 is the zero adjustment for the bridge. This control is mounted on the front panel of the receiver and is labeled "Zero Adjust." This control is adjusted so that the input meter indicates zero, when no signal is being received. This balances the bridge and no difference in potential exists across the meter. Potentiometer R368 is a screw-driver adjustment used to set the maximum deflection as required to compensate for conditions of variation in over-all gain, tube replacement, and so forth.

If a-v-c voltage is applied to the grid of V301, its plate current and the current through resistor R309 decreases, unbalancing the bridge, causing current to flow through the meter. The amount of unbalance of the bridge depends on the amount of a-v-c voltage which in turn de-

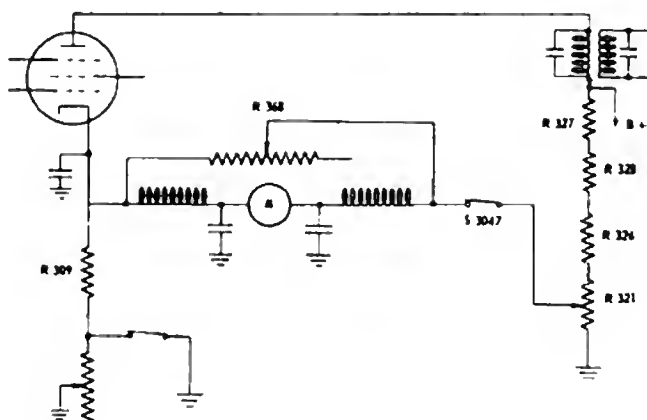


Figure 7-8.—Simplified diagram of the input meter circuit.

depends on the strength of the received signal. The greater the strength of the received signal, the greater the deflection on the meter. The meter is calibrated in decibels using 1 microvolt as the reference level. Maximum deflection is 120 db, which corresponds to a 1-volt signal input at the antenna.

### C-W Oscillator

Placing the reception transfer switch in the CW position applies plate voltage to the beat frequency oscillator (BFO). A simplified schematic diagram with the reception transfer switch in the CW position is shown in figure 7-9,A, and in the CW-OL position, figure 7-9,B. The circuit for CW-OL operation is the same as for CW operation except that the output limiter circuit is connected in the former and not in the latter. The output of the BFO is coupled to the cathode of the detector tube and





changes in signal strength. The reception transfer switch in the CW-OL position places V308 in the circuit as an audio amplifier. This added amplification is needed to raise the audio level to a value high enough to ensure efficient limiting action. Varying the position of the OUTPUT LEVEL control R363B varies the positive cathode bias on V306. A signal coupled through capacitor C323 must have an amplitude greater than this bias, if V306 is to conduct and limit the signal. Tube V306 limits the positive portion of the audio signal while V309 limits the negative portion. The output is capacitively coupled to the second audio amplifier.

The second audio amplifier and the audio power amplifier are shown in figure 7-10. These stages are conventional in design. Negative feedback is used to keep the audio output of the receiver constant when the load is varied across the output transformer. Meter M301 is a voltmeter mounted on the receiver front panel. It indicates the plate voltage of the receiver. Meter M303 is the output meter and is similar to the output meter described for the RBA receiver in chapter 6.

The power supply is a conventional full-wave circuit with a regulated output. All of the output voltages of the power supply are connected to receptacles on the front panel and then through a cable to the receiver. A schematic diagram of the power supply is shown in figure 7-11. In an emergency two receivers may be operated from the same power supply.

## **MODEL FRA FREQUENCY-SHIFT CONVERTER**

Chapter 4 contains a discussion of the model FSB frequency-shift keyer used to change the output of a teleprinter into frequency variations of an r-f carrier. At a receiving station a standard Navy receiver in conjunction with a suitable converter changes the signals back into their original form. The output of the converter

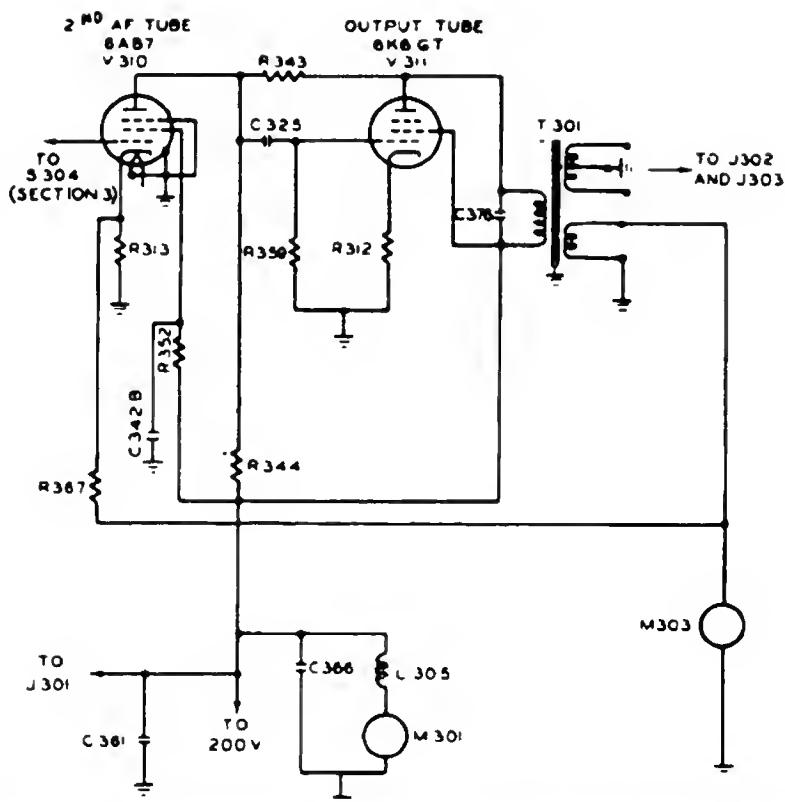


Figure 7-10.—Simplified schematic diagram of the second audio amplifier and the power amplifier.

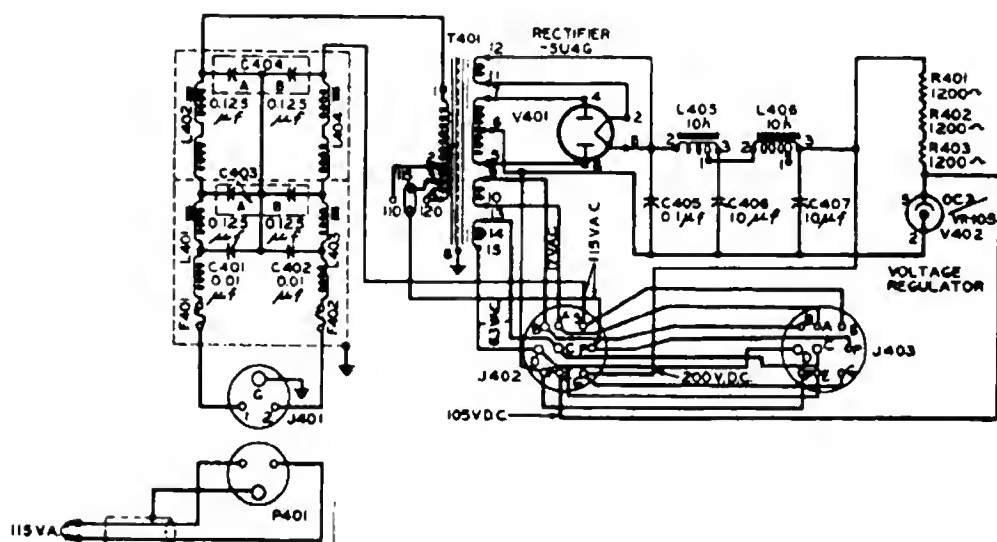


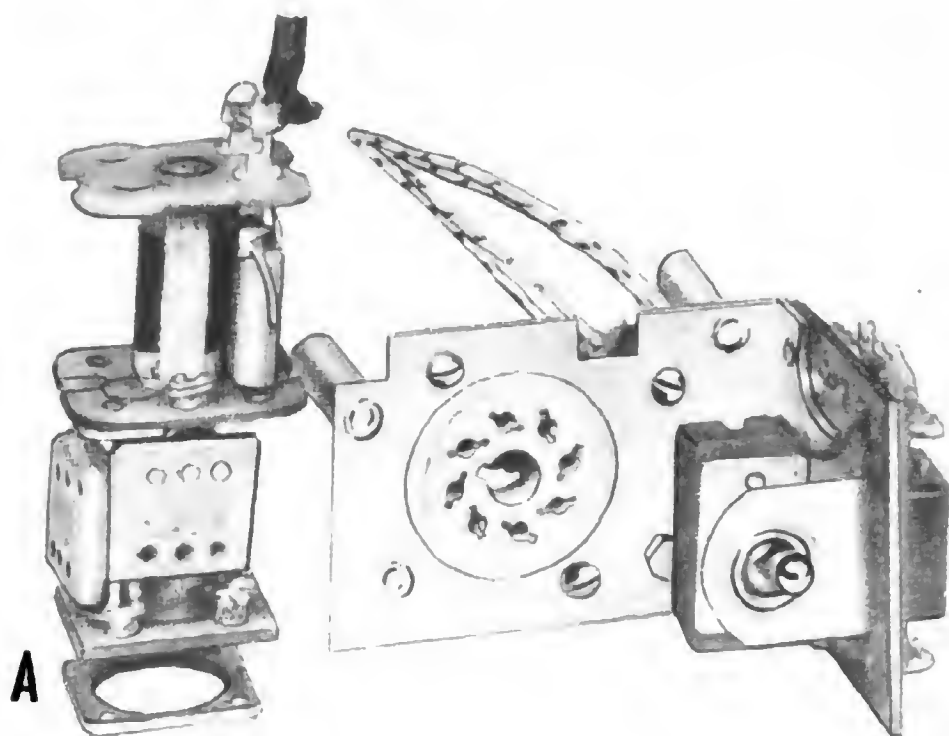
Figure 7-11.—Schematic diagram of the power-supply unit.

is a series of d-c pulses which actuate the selector magnets in the receiving teletypewriter. The FRA frequency-shift converter used in conjunction with an RBB receiver for teletypewriter application is described in this chapter. A photograph of the FRA is shown in figure 7-12.

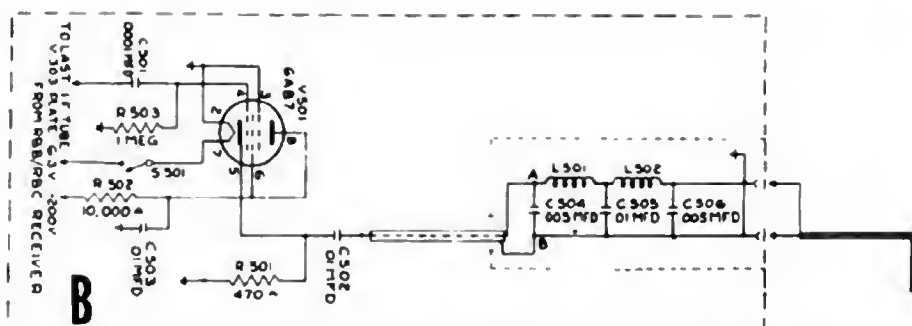


**Figure 7-12.—Model FRA frequency-shift converter.**

The converter is connected to the receiver through a coupling kit. A photograph of the component in Navy type CRV-10563 coupling kit used to connect the RBB to the FRA is shown in figure 7-13,A. A schematic of the coupling kit is shown in figure 7-13,B. The input of the kit is coupled through capacitor C501 to the plate of the last i-f amplifier in the RBB receiver. The coupling kit adds a small amount of capacity across the last i-f transformer which makes it necessary to readjust this transformer to resonance after the connection is made. Pentode V501 is connected as a cathode-follower stage having a low output impedance. The cathode follower



**A**



**B**

**Figure 7-13.—Coupling kit Navy type CRV-10563. A, Photograph, B, schematic.**

has a high input impedance which insures that the receiver i-f stage is not loaded appreciably. The low output impedance makes it convenient to connect the kit to the converter through a coaxial cable. A low-pass filter is included in the coupling kit to prevent any signals above 550 kc from entering the converter. Plate and filament voltage is obtained from the receiver.

A schematic diagram of the FRA converter is shown in figure 7-14. The input to the converter is fed through jack J204 to the primary of transformer T101. This transformer matches the low impedance of the coaxial cable to the high impedance of the input grid circuit. Tube V101 functions as an ordinary i-f amplifier stage. The output of the i-f amplifier is coupled to the grid of limiter V102. The limiter stage provides a constant amplitude signal for the locked oscillator. The high resistance of R106 reduces the limiter screen voltage to a very low value. Because of the low screen voltage and very small plate load resistor any signal applied to the limiter grid appears at the output as a signal of small constant amplitude.

### Limiter and Locked Oscillator

The constant amplitude signal varying from 425 cycles above to 425 cycles below a center frequency is the input to the locked oscillator. For the RBB the center frequency is 400 kc.

If two self-excited oscillators are closely coupled and are oscillating near the same frequency, they tend to lock in together and synchronize. In the case of the FRA the input signal is closely coupled to the locked oscillator and therefore the frequency variations of the input signal are imparted to the output of the oscillator. (The grids of V103 are referred to by numbers starting with the grid closest to the cathode as number 1.) The input signal is placed on grid 1. Grids 2, 4, and 3, together with the cathode form a triode connected as an oscillator. This oscillator is tuned to 400 kc.

The input signal has a center frequency of 400 kc and the two signals lock in. Grid 1, grid 2, grid 4, and the cathode form a triode amplifier. Since the plate of the triode amplifier and the plate of the oscillator are the same element, any frequency variations of the input vary

the frequency of the locked oscillator. The output of the locked oscillator is coupled to the plate of V103 through the electron stream and appears across the discriminator transformer T104.

The amount of frequency variation or shift of the locked oscillator depends on the amplitude of the input signal as well as the frequency variations of the input signal. Changing the amplitude of input signal with S101 changes the amount of variation of the locked oscillator output frequency. The narrow position of S101 is used to prevent a strong interfering signal near the frequency of the received signal from locking in with the locked oscillator.

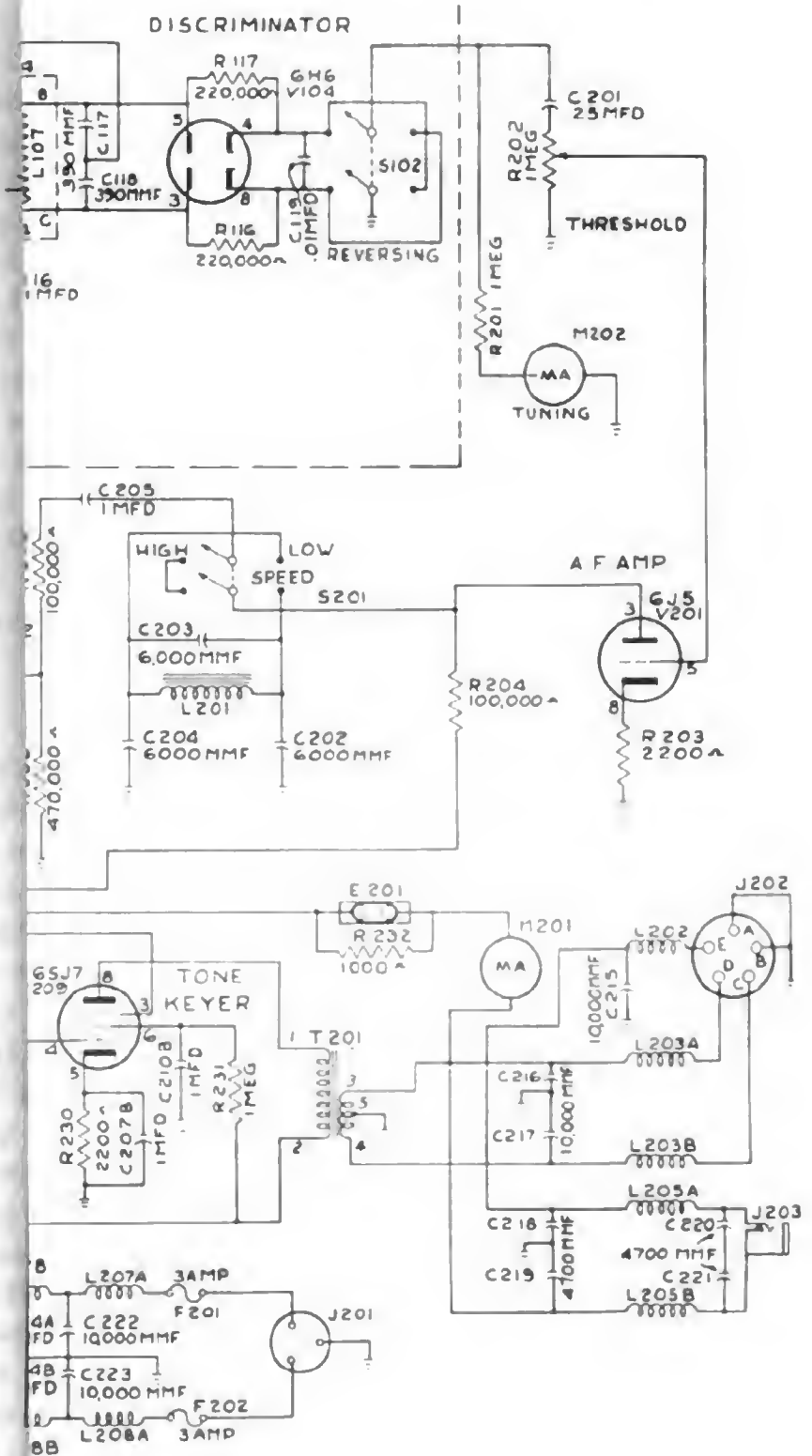
### Discriminator

The output of the locked oscillator is fed to a Foster-Seeley discriminator circuit where the frequency variations are converted into amplitude variations. The output of the discriminator is essentially d-c pulses like the d-c pulses fed originally to the frequency shift keyer.

Meter M202 is the tuning indicator. To use the indicator tune a signal in on the receiver. As the frequency of the receiver approaches the frequency of the signal, the meter needle suddenly moves to one side of the scale. Tuning the receiver farther in the same direction causes the meter needle to pass through zero and move to the other side of the scale an equal amount. Correct tuning of the receiver is achieved when the meter needle passes through zero. However, if the transmitter is sending out a steady mark, the needle does not indicate zero for correct tuning of the receiver, but normally moves to the right of the zero mark. With a normal signal the average output of the discriminator, as far as the meter is concerned, is zero and the meter needle indicates zero.

Meter M202 is actually a voltmeter which measures the output voltage of the discriminator. Switch S102 is the output reversal switch. In normal frequency shift

# DISCRIMINATOR







keying operation the mark output of the teletypewriter causes the transmitter frequency to increase while the space output causes it to decrease. It is possible that in some cases the reverse situation may be true. The FRA converter output will then have the reverse polarity of the original marks and spaces. Changing the position of switch S102 restores the correct polarity of the signals. Output from the discriminator is coupled through capacitor C201 and appears across THRESHOLD control R202, which controls the input to the audio amplifier.

The audio amplifier amplifies the d-c pulses and its output is connected to SPEED switch S201. In the HIGH position the signals are coupled directly through capacitor C205 to the locking circuit. In the LOW position the signals pass through a low-pass filter which attenuates high frequency noise above 200 cycles.

### Locking Circuit

In order to hold either long space or locking circuit mark signal until a pulse of the opposite polarity is received, as might be the case in receiving facsimile signals, a locking circuit is incorporated in the FRA converter. The locking circuit, V202 and V203, is similar in operation to an Eccles-Jordan multivibrator circuit. The locking circuit has two steady state conditions, (1) either V202 is conducting and V203 is cut off or (2) V202 is cut off and V203 is conducting. Normally V202 is conducting when the transmitting equipment is sending a SPACE signal and nonconducting when the transmitter is sending a MARK signal.

Consider the first condition of the circuit with V202 conducting and V203 cut off (when the transmitting equipment is sending a space signal). A negative pulse applied to the grid of V202 reduces its plate current and the plate voltage increases. The increased plate voltage is coupled to the screen grid of V203 causing V203

to conduct. When V203 conducts, its plate current increases and its plate voltage decreases.

The decreasing plate voltage is coupled to the screen grid of V202. The decreased screen voltage is sufficient to cut off V202. Now the original conditions are reversed. V202 is cut off and V203 is conducting. If another negative pulse is placed on the grid of V202, nothing happens because the tube is already cut off. However, a positive pulse corresponding to a transmitted MARK signal will cause tube V202 to conduct thereby reducing the screen voltage of V203 and causing the latter tube to cut off. This corresponds to condition (1) in which the locking circuit is in readiness to receive a negative pulse (SPACE signal from the transmitter).

### Mark Return Circuit

A MARK RETURN circuit prevents the locking circuit from remaining in the SPACE condition for longer than 200 milliseconds—that is, it prevents V203 from remaining cut off for a period longer than 200 milliseconds. The mark return circuit is composed of V204 and its associated components.

If a burst of noise causes V203 to cut off (corresponding to a steady space signal) the mark return circuit after 200 milliseconds returns the locking circuit to the steady mark condition in which V203 is conducting and V202 is cut off. Placing S202 in the ON position connects an *R-C* filter circuit from the plate of V203 to ground. After 200 milliseconds C207A charges to about 105 volts which is sufficient to cause the VR-75 tube to conduct. The voltage across C207A immediately decreases to 75 volts and the discharge of C206 applies a negative pulse to the grid of V202 cutting this tube off.

As soon as V202 is cut off V203 returns to a conducting condition. When V203 is conducting, its plate voltage is not sufficient to charge C207A enough to fire

the VR-75 tube. The circuit remains at a steady mark condition until noise again operates the circuit or normal signals are received. Switch S202 is placed in the OFF position when receiving facsimile signals, since these signals may consist of long spaces (in excess of 200 milliseconds) and long marks.

### Squelch Circuit

The FRA also has a squelch circuit to insure that signals below a predetermined level will not operate the converter. The grid of squelch tube V205 is connected to a voltage divider. The voltage divider is connected between the grid of the limiter stage and ground. When a signal is received, the limiter develops grid leak bias across this voltage divider. Part of this bias is placed on the grid of the squelch tube. Resistor R219 and capacitor C210C form an  $R-C$  filter with a time constant of 200 milliseconds.

The  $R-C$  filter prevents peaks of noise from actuating the squelch tube. The plate of the squelch tube is connected through a resistor to the plate of tube V203 in the locking circuit. The plate current of V205 and V203 flows through a common resistor, R233. With no signal input to the converter no grid leak bias is developed by the limiter and no bias is applied to the squelch tube. If the MARK RETURN switch S202 is on, V203 is conducting and its plate voltage is low. The lack of bias on the squelch tube causes still more current to flow through the common load resistor. The plate current of the squelch tube further reduces the plate voltage on V203 keeping the locking circuit in a steady mark condition. With no signal being received, the gain of the receiver is adjusted to the point where the squelch tube just conducts. When a signal is received, the limiter develops grid leak bias and cuts off the squelch tube which decreases the current through R233 and restores normal plate voltage to V203. The locking circuit now operates normally.

The amount of grid leak bias needed to cut off the squelch tube is constant. However, adjusting the gain control of the receiver varies the amplitude of the signal coupled to the converter. If only a small amount of the received signal is coupled to the converter, a strong signal input to the receiver is needed to develop the bias to cut off the squelch tube. A weak signal would be amplified in the converter as much as a strong signal, but the amplitude of the weak signal would not be sufficient for the limiter to develop enough bias to cut off the squelch tube. As a result the converter would remain in the steady mark condition. Obviously the receiver gain should be increased sufficiently to eliminate this condition.

### **Power Locking Stage**

The POWER LOCKING STAGE (V206, V207, and associated power supplies) is used to obtain the necessary power to actuate a teletypewriter. Two arrangements of the power locking stage are possible. One position of switch S203 provides for polar operation and the other position provides for neutral operation. The operation of the power locking circuit is similar to the operation of the locking circuit (V202 and V203).

A simplified schematic diagram of the circuit for polar operation is shown in figure 7-15,A. Assume that a steady mark signal is being received. Tube V206 is conducting and V207 is cut off. The path of current flow for this condition is from the plate of V206 through the power supply, the center tap of the high voltage transformer, R213, R232, M201, the load, and the cathode of V206. The current flowing through R213 causes a voltage drop which is coupled through R214 to the grid of V207. Since this grid voltage is negative with respect to the cathode tube V207 is cut off. Tube V206 is cut off when a negative pulse is placed on its grid. Cutting off V206 removes the bias voltage from the grid of V207, since there is no



voltage drop across resistor R213. This allows tube V207 to conduct. Starting at the plate of V207 current flows through the other power supply, the center tap of the high voltage transformer, R211, the load, M201, R232, and the cathode of V207. Bias voltage for V206 is developed across R211. This bias keeps V206 cut off.

Rheostat R212 is used to adjust the amount of current flowing through the load. The rheostat has a front panel control labeled "DC Output." Meter M201 indicates the amount of current flowing through the load. From the foregoing explanation it can be seen that current flows in one direction through the load for a mark and in the other direction for a space. This corresponds to polar operation.

A simplified schematic diagram of the power locking circuit for neutral operation is shown in figure 7-15,B. In neutral operation current flows through the load only during the mark signals. Space signals produce no output. Assume that a steady mark signal is being received. Tube V206 is conducting and V207 is cut off. The path of current for this condition is from the plate of V206, through the power supply, the center tap of the high voltage transformer, R212, R232, M201, the load, ground, and the cathode of V206. If a negative pulse applied to the grid of V206 cuts off this tube, the bias developed across R212, R232, and the load is removed from the grid of V207 allowing this tube to conduct. Current flows from the plate of V207 through the power supply, the center tap of the other high voltage transformer, resistor R211, ground, and the cathode of V207. Notice that, when V207 conducts (corresponding to a space signal), no current flows through the load. This corresponds to neutral operation.

### **Tone Oscillator**

The tone oscillator, V208 figure 7-14, is a phase-shift oscillator. The output appearing at the plate is shifted

180° by an *R-C* phase-shifting network and is fed back to the grid to sustain oscillations. The oscillator operates continuously with its output coupled to the grid of the keyer tube through capacitor C214. The keyer tube normally is conducting and its output is fed to jack J202.

The bias developed across resistor R211, when V207 is conducting (corresponding to a space signal), is supplied to the suppressor grid of the keyer tube. The bias is sufficient to cut off the tube and interrupt the tone to jack J202. When a mark signal is received, the bias across R211 is zero and the keyer tube conducts, passing the tone to the jack. The tone can then be fed over telephone lines to another converter which excites a teletypewriter located at some point remote from the FRA converter.

## SCR-608 TRANSMITTER-RECEIVER

### General Description

The SCR-608 transmitter-receiver is an army equipment originally designed for installation in vehicles. However, many ships have this equipment for communications to units ashore and for gunfire support communications. The primary power for the SCR-608 usually is 12 or 24 volts batteries. High voltage for both the transmitter and the receivers is obtained from dynamotors. A photograph of the SCR-608 is shown in figure 7-16. The transmitter is crystal-controlled and employs frequency modulation. The normal power output of the transmitter is 20 watts. The transmitter and the receivers cover the frequency range from 27.0 to 38.9 Mc. Any one of ten preset frequencies may be selected by push buttons on the transmitter and on the receivers. In addition to push-button tuning the receiver tuning is continuously variable as in the conventional type of receivers.

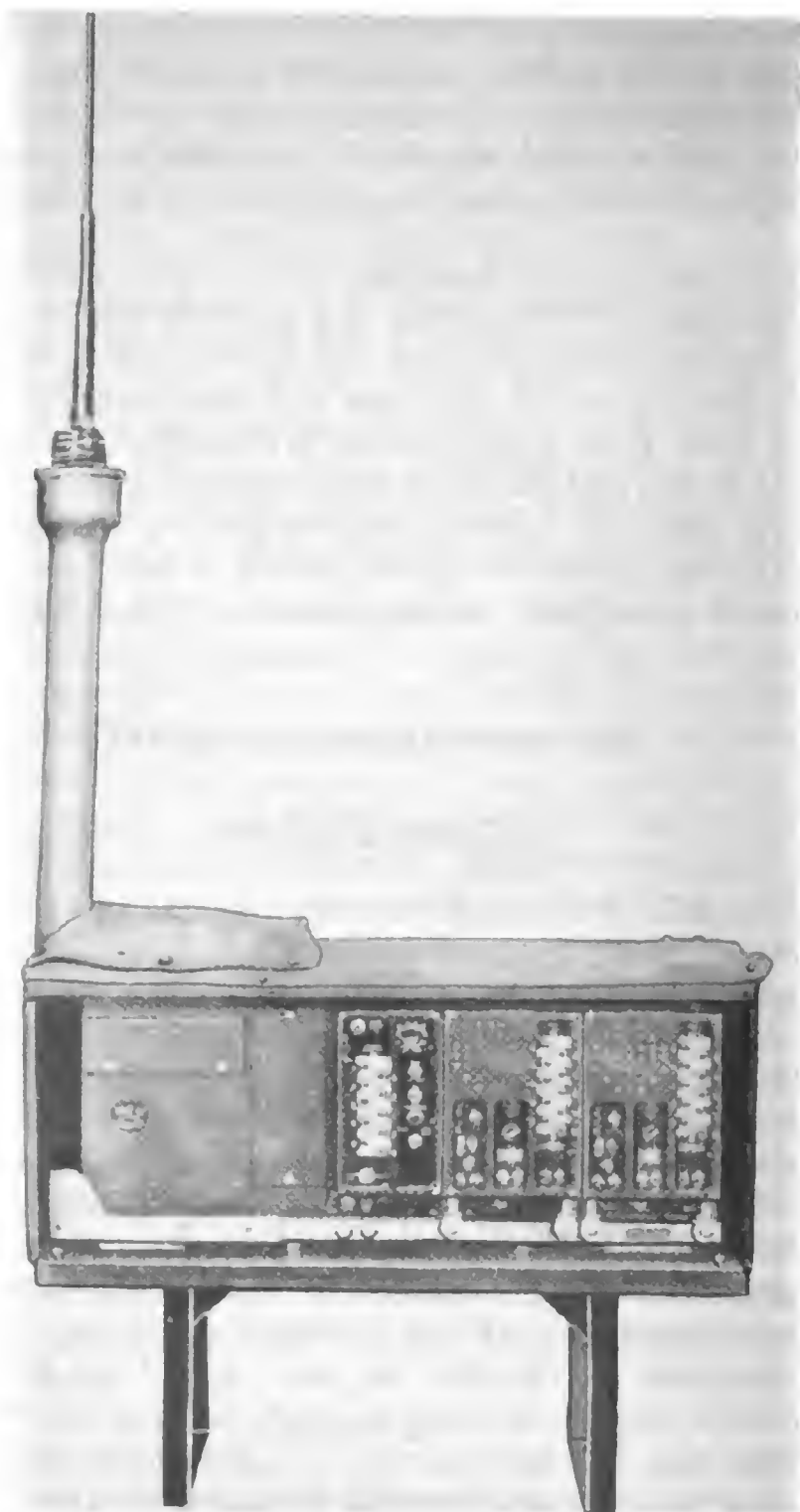


Figure 7-16.—SCR-608 transmitter-receiver.



## BC-684 Transmitter

Most of the stages of the BC-684 transmitter are conventional with the exception of the circuits used to obtain the frequency modulation. A simplified diagram of this transmitter is shown in figure 7-17. The first stage of the

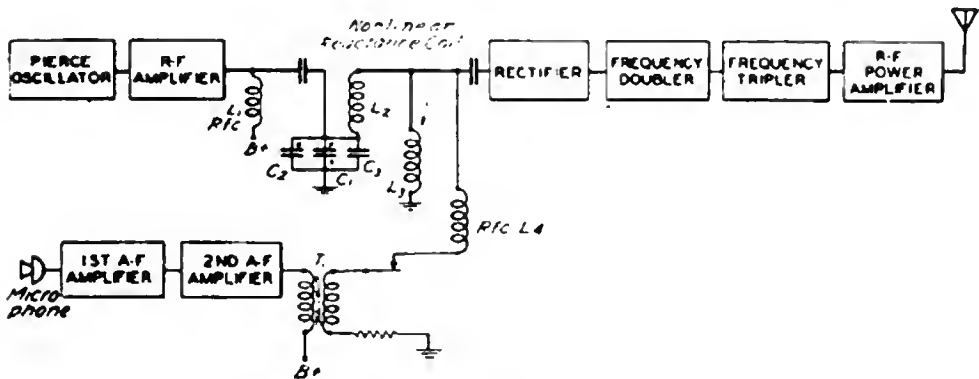


Figure 7-17.—Simplified diagram of the f-m transmitter BC-684.

transmitter is a crystal-controlled oscillator which operates with any one of 80 crystals. The frequencies of these crystals range from 370.37 to 516.667 kc. The output of the oscillator is coupled to an r-f amplifier which isolates the oscillator from the following stages and also provides some amplification. The plate of the r-f amplifier is shunt fed through an r-f choke.

The output of the r-f amplifier is impressed across the tuned tank circuit containing a nonlinear reactance coil. This coil saturates with low values of r-f current and sharp pulses of voltage are produced as shown in figure 7-18. The flux is changing at its fastest rate between points A and B causing a pulse of induced voltage. Above point B the nonlinear coil is saturated and the increasing r-f current causes negligible change in flux, hence negligible induced voltage in the coil. Between points C and D the current is again below the amount required to saturate the coil and the rapid change of flux causes a second pulse of voltage, this one of opposite

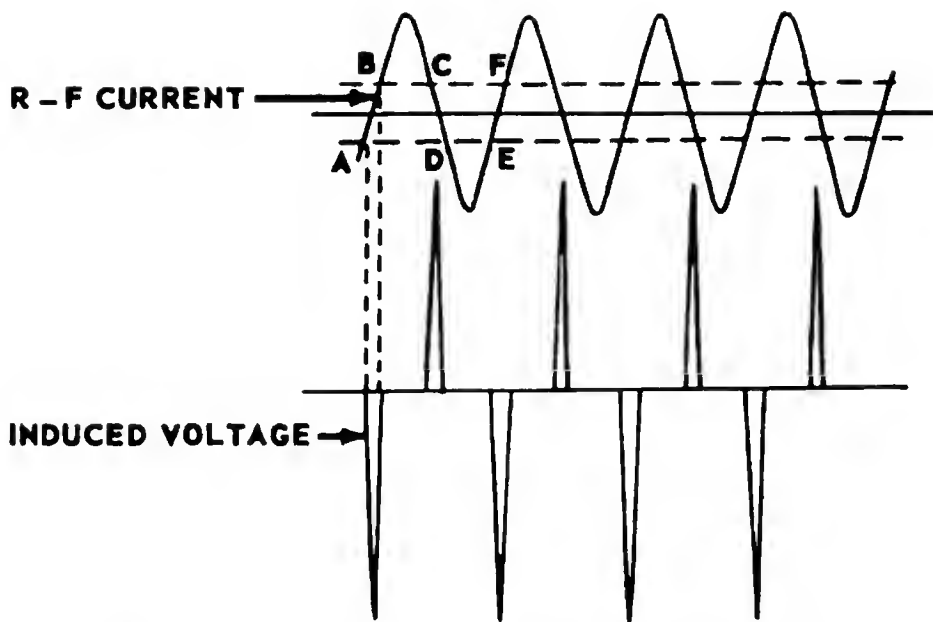


Figure 7-18.—Voltage pulses developed across the nonlinear reactance coil.

polarity to the first. The induced voltage pulses are in quadrature with the r-f current when only the output of the r-f amplifier is applied across the coil.

During modulation the audio amplifier output in addition to the r-f amplifier output is applied across the nonlinear coil. The input and output waveforms of the nonlinear coil for this condition are shown in figure 7-19. The r-f carrier current (figure 7-19,A) and the voice current (figure 7-19,B) add to produce the resultant current in figure 7-19,C. The audio (voice) current is shown as only a single frequency. The points at which the combined currents go through zero do not occur at the same instant of time as for the pure r-f current. Therefore the pulses of induced voltage developed across the nonlinear coil no longer occur at regular intervals but vary in time as shown in figure 7-19,D. Changing the time at which the induced voltage pulses occur is equivalent to varying their frequency. However, this is not true frequency modulation. It is actually phase modulation. The broken

vertical lines in the figure pass through the points at which the combination of r-f and a-f currents is zero. By comparing the zero points for the combined currents with the zero points for the pure r-f current, the time differences can be noted.

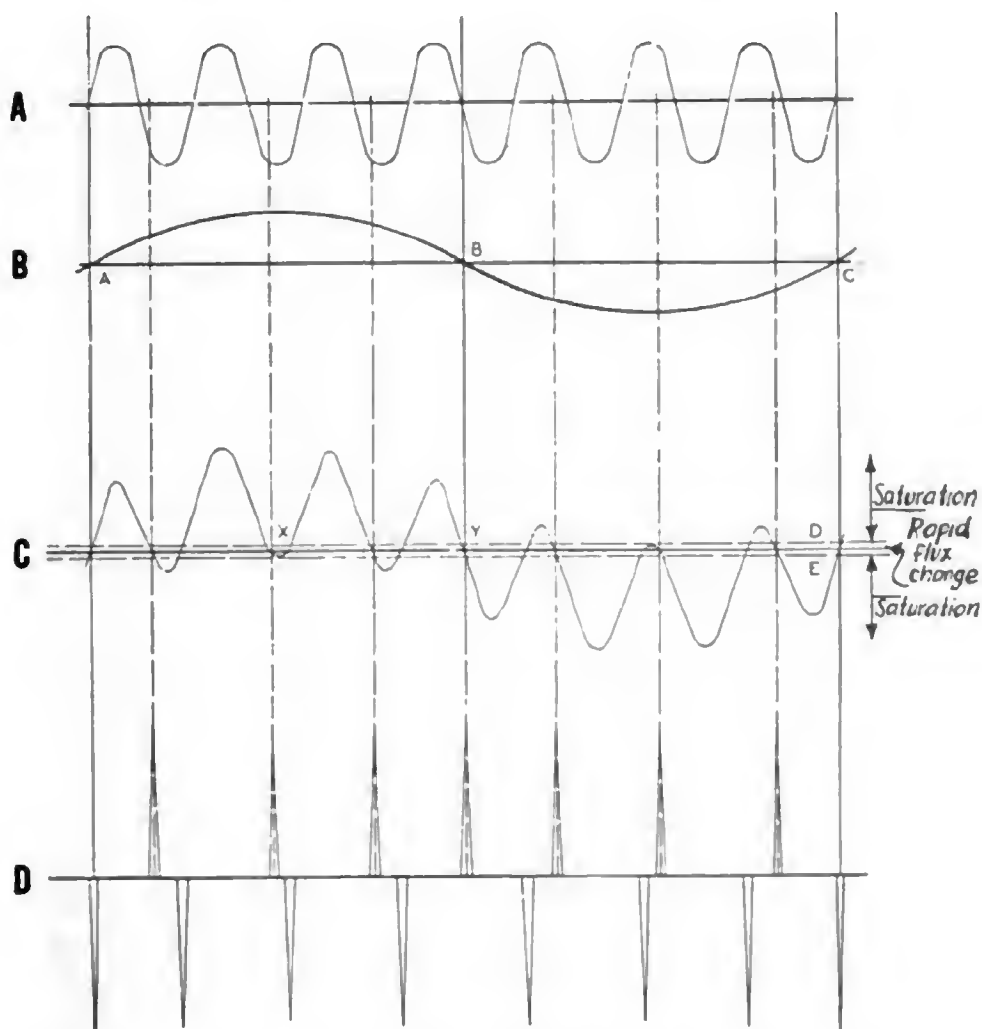


Figure 7-19.—Input and output waveforms of the nonlinear coil. A, r-f current, B, a-f current, C, combination of r-f and a-f, D, inductive pulses of voltage.

In f-m systems which use phase modulation it is necessary to prevent a signal that changes in audio frequency but remains at constant amplitude from influencing car-

rier swing. In a true f-m transmitter the carrier frequency deviation depends only on the amplitude of the a-f signal. In the phase modulation system the carrier deviation depends on both the amplitude and the frequency of the audio signal. This condition is eliminated by varying the gain of the audio amplifier inversely with the audio frequency.

The output of the nonlinear coil contains both positive and negative voltage pulses. Because of the time relation between the positive and negative pulses, one set must be eliminated to prevent serious frequency distortion. This elimination is accomplished in the rectifier stage following the nonlinear coil. The rectifier is actually a class-C amplifier. Since this stage is biased beyond cutoff, the negative pulses are eliminated from the output.

The output of the nonlinear coil has a strong ninth harmonic content. The plate circuit of the rectifier is tuned to this harmonic. The amount of frequency deviation obtained in the nonlinear coil is small. However, in frequency multiplier stages following the nonlinear coil, the deviation is increased. The frequency of the voltage pulses is multiplied 54 times in the stages following the nonlinear coil.

### **BC-683 Receiver**

The BC-683 is a 10-tube superheterodyne receiver capable of receiving frequency modulated signals from 27.0 to 38.9 Mc. Any one of ten preset frequencies may be selected by pressing the correct push button. The entire range of the receiver can be covered also by the manual tuning control. A block diagram of the BC-683 is shown in figure 7-20. The r-f, i-f, and discriminator circuits are conventional. An i-f oscillator is used for alignment.

A delayed automatic volume control circuit in the receiver reduces the gain of the r-f and the first i-f amplifiers for strong incoming signals. To prevent the gain of the receiver from being reduced on weak signals, a

delay bias is placed on the delayed a-v-c diode. The sensitivity control determines the amount of bias on the diode and, therefore, determines how large the incoming signal must be to operate the delayed a-v-c circuit.

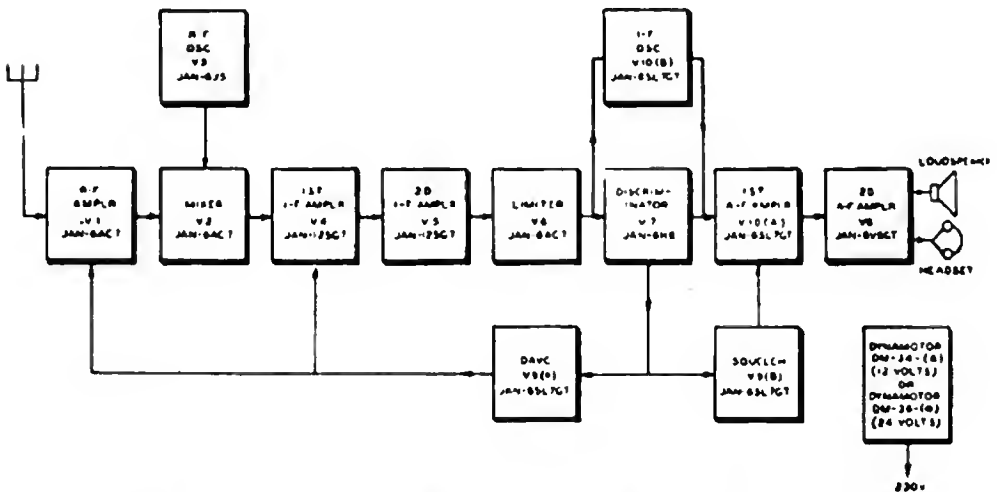


Figure 7-20.—Block diagram of the BC-683 receiver.

Figure 7-21 is a schematic diagram of the delayed a-v-c circuit. A positive bias obtained from the voltage divider is placed in series with the negative component of the discriminator output to the cathode of the delayed a-v-c diode. When no signal is being received, there is no discriminator output and only the bias appears on the cathode. In this condition the cathode is positive with respect to the plate and the diode does not conduct. The sensitivity control may be used to vary the amount of positive bias by changing the current through the voltage divider. When a signal is received, the d-c component of the discriminator output being negative subtracts from the positive voltage on the cathode of the delayed a-v-c diode. If the d-c voltage is large enough, the diode will conduct.

A negative bias is placed on the grids of the r-f and the first i-f amplifier because of the voltage drop across the sensitivity control and across resistor R24. However,

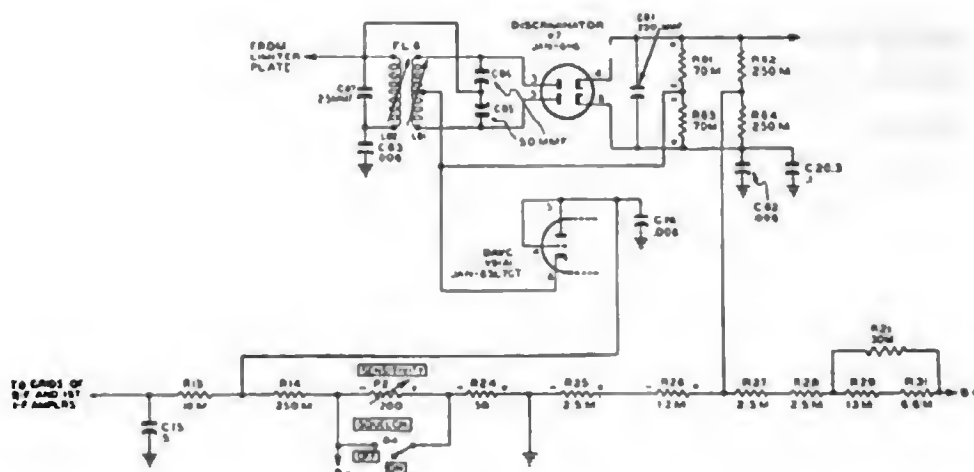
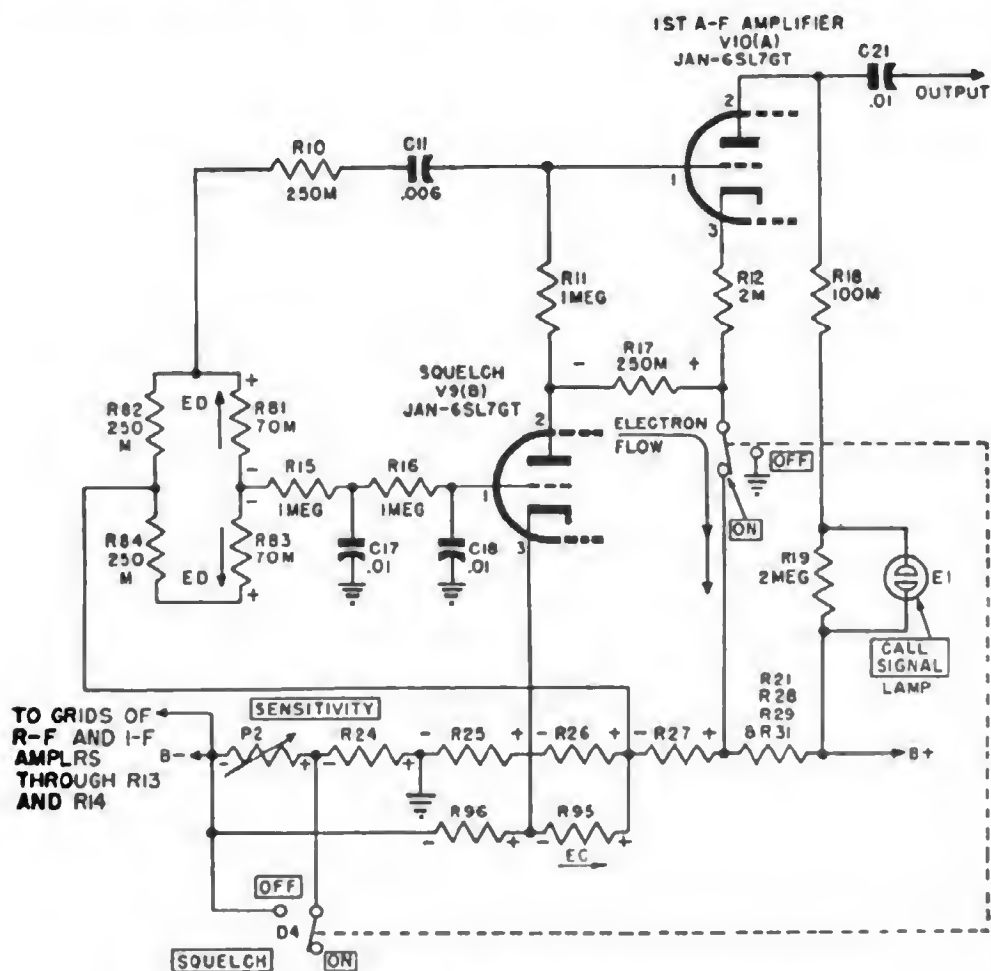


Figure 7-21.—Schematic diagram of the delayed a-v-c circuit.

when the diode conducts, an additional bias is placed on these grids because of the voltage drop across resistor R14. This voltage reduces the gain of the r-f and the first i-f amplifiers. The greater the discriminator voltage, the greater the current through the diode and the greater the additional bias. Resistors R82 and R84 are isolating resistors to prevent the audio signal appearing across the discriminator from being affected by the voltage divider. The SENSITIVITY control also controls the amount of fixed bias to the r-f and i-f amplifiers.

A squelch circuit is incorporated in the BC-683 receiver to block the first audio amplifier tube, when no signal is being received and thereby eliminates noise from the speaker between transmissions. A schematic diagram of the squelch circuit is shown in figure 7-22. The voltage drop across resistor R95 is applied between the grid and cathode of the squelch tube. The grid is positive with respect to the cathode and the tube conducts. The plate current flows through resistor R17 and develops a bias voltage on the grid of the first a-f amplifier. The grid is negative with respect to the cathode and the first audio amplifier is cut off. No output is heard from the receiver. When a signal is received, the negative d-c component

of the discriminator signal opposes the positive bias across resistor R95. If the discriminator output is suf-



**Figure 7-22.—Schematic diagram of the squelch circuit.**

ficient, the squelch tube is cut off and the negative bias on the grid of the first audio amplifier is removed. This permits normal operation of the first audio amplifier.

The CALL SIGNAL lamp lights when a signal is received which is strong enough to cut off the squelch tube. With the squelch tube cut off, the audio amplifier tube conducts, and sufficient voltage is developed across resistor R19 to fire the lamp. The sensitivity control determines the strength of signal needed to cut off the squelch tube.

This control varies the gain of the r-f and the first i-f amplifiers. The sensitivity control indirectly controls the output of the discriminator which sets the operating point of the squelch circuit. The sensitivity control is usually adjusted to the point where the call lamp just goes out when no signal is received. To receive weak signals, the squelch circuit is usually disabled by switch D4. The audio amplifiers are conventional *R-C* coupled amplifiers.

## QUIZ

1. What is the maximum communications range of the ground wave at the low end of the high-frequency band?
2. What portions of the medium-frequency band and the high-frequency band are generally used for long range communications?
3. What antenna systems are generally used aboard ship for receiving signals in the m-f and h-f bands?
4. What is the frequency range over which a rhombic antenna is generally designed to operate?
5. What is the characteristic impedance of a rhombic antenna?
6. What separate units are contained in the i-f/a-f section of the RBB/RBC receivers?
7. What separate units are contained in the preselector unit of the RBB/RBC receivers?
8. What measure is taken in the RBB/RBC receivers to protect the first tuned circuit from damage by a nearby transmitter?
9. Why are the padder capacitors (C108, C109, C110, and C111) connected in series with the oscillator tuning capacitor?
10. How does the radio selectivity switch vary the selectivity of the RBB/RBC receiver?
11. In the RBB/RBC receivers, which i-f stage does not have a-v-c voltage applied to it?
12. (a) Can the noise limiter in the RBB/RBC receivers reduce the level of a noise pulse below that of the desired audio signal? (b) Why?



13. What, basically, is the difference between the effect of the control marked "output level" (figure 7-9, B) and the control marked "gain control" (figure 7-5) in the RBB/RBC receivers?
14. What does the input meter of the RBB/RBC receivers actually indicate?
15. What is the relative magnitude of the input and output impedance of a cathode follower?
16. When the Foster-Seeley discriminator of the model FRA converter is properly tuned, what does meter M202 (figure 7-14) indicate as its dial reading?
17. How can the polarity of the output pulses of the FRA converter (figure 7-14) be reversed?
18. How does pentode V203 in the FRA converter respond to noise signals?
19. What system of modulation does the SCR-608 transmitter-receiver use?
20. What is the frequency range of the BC-683 receiver?



## **V-H-F AND U-H-F RECEIVERS**

### **DESIGN FEATURES**

Receivers for operation in the v-h-f and u-h-f bands are superheterodyne types which require special design features not encountered in low frequency equipment. V-h-f and u-h-f transmitters also require special design features not needed in the lower frequency bands. As the frequency is increased, many components develop limitations which require special consideration. Items such as lead length, insulators, tubes, wiring capacities, circuit components, and physical lay-out of the components become increasingly important.

Superheterodyne receivers require a local oscillator or frequency converter. The local oscillator in a v-h-f or u-h-f receiver constitutes a difficult design problem from the standpoint of achieving frequency stability. In the RDZ receiver the local oscillator includes a frequency converter the output of which operates at a frequency 15.1 Mc higher than the incoming signal. This receiver may be tuned from 230.6 to 389.8 Mc. Therefore, the converter output has a frequency range of 245.7 to 404.9 Mc.

To overcome the difficulty of unstable operation of the oscillator at such high frequencies, the converter employs four frequency multiplier stages with the oscillator itself operating at much lower frequencies. The out-

put of the oscillator is fed to a series of frequency multiplier stages. The output of the last frequency multiplier is mixed with the incoming signal to produce the intermediate frequency.

A disadvantage of this method is the large number of tuned circuits in the multipliers. Unlike many low-frequency receivers the RDZ does not employ band-switching.

Another point to consider is whether the receiver is to be continuously tunable or crystal controlled. The crystal-controlled receiver has the advantage of remaining exactly on frequency. This is an advantage for communication purposes. However, if a large number of frequencies are to be covered a large number of crystals are required. A continuously variable receiver is useful for intercept and countermeasure purposes. The RDZ is a crystal-controlled receiver that may be preset to ten different channels. The RBK receiver, which covers the lower half of the v-h-f band, is a bandswitching continuously tunable receiver. To analyze received signals, a panoramic adaptor may be connected to either the RBK or the RDZ receiver.

## MODEL RBK RECEIVER

The RBK receiver is a superheterodyne receiver covering the lower half of the v-h-f band (27.8 to 143 Mc). This receiver is capable of receiving either amplitude modulated or frequency modulated signals. The A-M/F-M switch on the front panel switches the output of the i-f amplifiers from a diode detector on a-m operation to a limiter and discriminator on f-m operation.

The RBK receiver is a Hallicrafters S-27D receiver (figure 8-1). Certain models of this receiver made for the Navy are provided with a jack connected to the primary winding of the first i-f transformer. A panoramic adaptor may be connected to this jack. In some cases the



Figure 8-1.—Model RBK receiver.

RBK has been used as an intercept receiver for radio countermeasures and in other installations as a companion

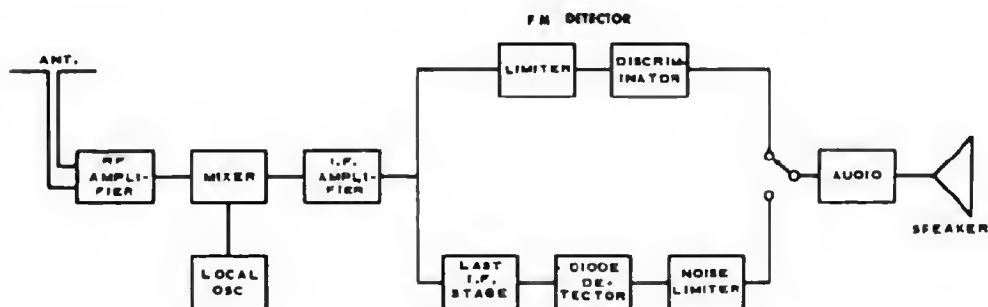


Figure 8-2.—Block diagram of the RBK receiver.

ion receiver for the TDQ transmitter. The frequency range of this receiver is covered in three bands.

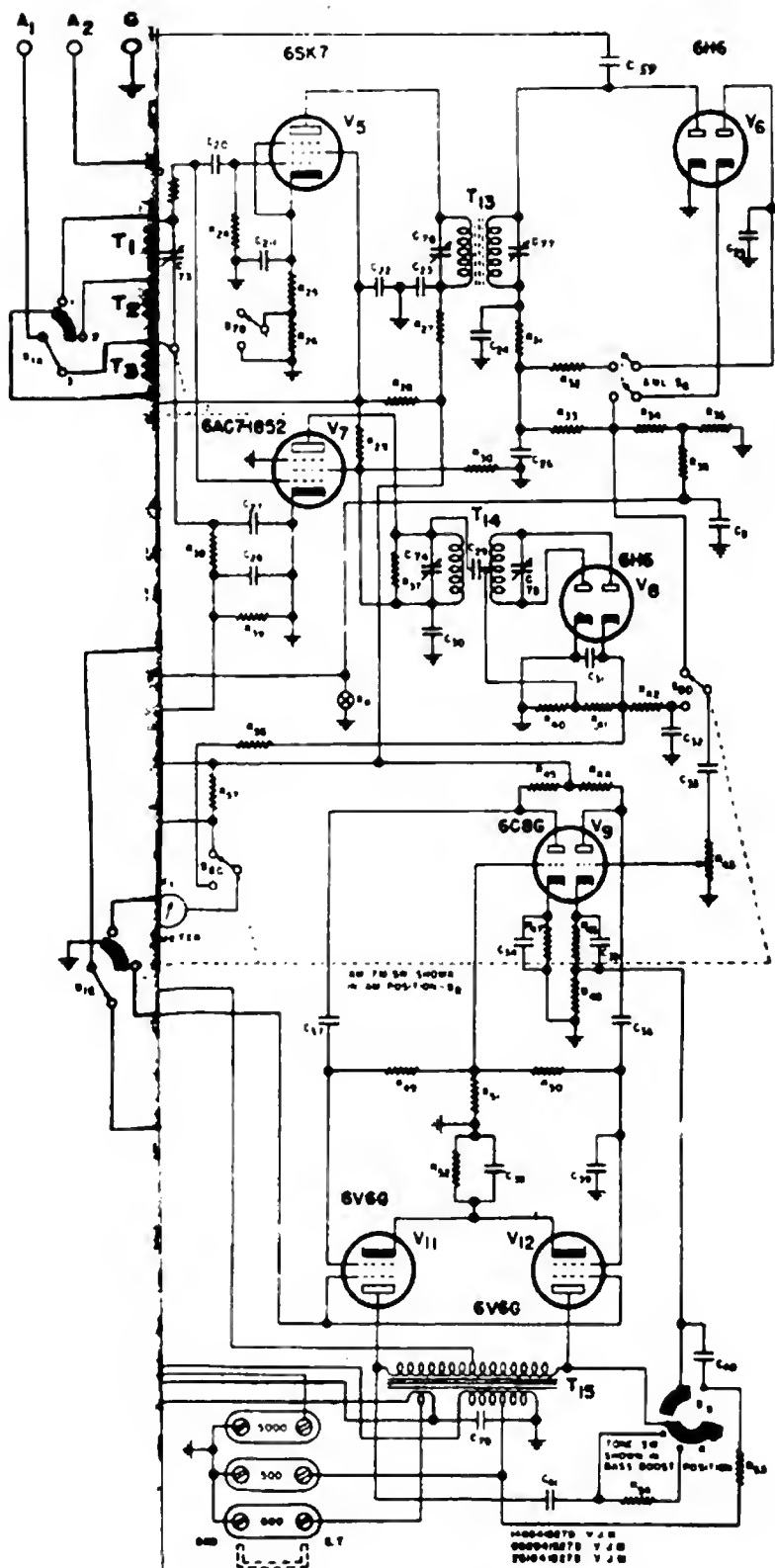
A block diagram of the RBK is shown in figure 8-2. The r-f amplifier, mixer, local oscillator, first two i-f stages, and the audio amplifiers are used for the reception of both a-m and f-m signals.

A schematic diagram of the RBK is shown in figure 8-3. Capacitors C1A, C1B, and C1C are sections of the ganged tuning capacitor. Capacitor C1A tunes the r-f amplifier, C1B tunes the mixer, and capacitor C1C tunes the local oscillator. Switches S1A through S1F are sections of the band switch. The band switch is shown on the diagram in the high frequency position. The A-M/F-M switch S8 is shown in the a-m position.

The r-f amplifier is conventional in design. Capacitor C7 is used to provide uniform coupling from the r-f amplifier to the mixer over the frequency range of the receiver. As the receiver is tuned to higher frequencies, the shunting effect of the transformer distributed capacitance tends to reduce the r-f output through the transformer coupling. At the same time the reactance of the coupling capacitor also decreases. This increases the amount of signal coupled to the mixer through the coupling capacitor and compensates for the loss in signal coupled through the transformer.

The BROAD-SHARP switch, S7, is shown in the SHARP position. When this switch is placed in the BROAD position, a small inductor and a resistor are placed in series with the secondary winding of each i-f transformer. Their purpose is to increase the bandpass. The resistor lowers the  $Q$  of the tuned circuit. The inductor increases the coupling between the primary and secondary windings. When the bandpass of the i-f amplifiers is increased, their gain is decreased. When switch S7 is placed in the BROAD position, switch section S7D removes part of the cathode bias on the last i-f stage, thus increasing its gain. This compensates for the reduced gain of the i-f stages and keeps the output of the receiver constant when the selectivity switch is changed.

The r-f gain control R11 is located on the front panel of the receiver. It is used to vary the cathode bias on the first two i-f amplifiers. The S-meter M1 provides an







indication of the strength of a-m signals. For f-m operation the meter is used as a tuning indicator. The meter itself is a special instrument with a basic movement of 150-0-50 microamperes.

Switch S3, the meter OFF-ON switch, is attached to the shaft of the r-f gain control. For a-m reception the S meter operates only when the AVC switch is on. Also, the r-f gain control must be advanced fully clockwise to close switch S3. The meter is connected so that the plate current of V4 causes the meter to deflect to the left.

When an a-m signal is received, a-v-c voltage is developed and the plate current of V4 is reduced. The amplitude of the a-v-c voltage depends on the amplitude of the received signal. Since the a-v-c voltage is applied to the control grid of V4, the plate current of V4 depends upon the amplitude of the a-v-c voltage. The greater the amplitude of the received signal, the greater the amplitude of the a-v-c voltage and the less the plate current through V4. Reducing the plate current causes the meter needle to move toward the right-hand end of the scale.

The meter scale is calibrated in S-units up to S9 and in decibels over S9. Resistor R57 is a meter shunt that bypasses most of the plate current around the meter. Rheostat R58 in series with the meter is a screw-driver adjustment on the front panel. It is used to adjust the meter to full scale (extreme left side of the meter) with no signal input to the receiver.

Placing switch S8 in the f-m position changes the S meter circuit into a tuning indicator circuit. With the switch in this position the meter measures the output voltage of the discriminator. When no signal is being received, the meter pointer is at the meter zero (about three-quarters of the full-scale reading toward the right end of the meter scale). As an f-m signal is tuned in on the receiver, the meter pointer indicates first on one side

of the zero mark and then passes through zero to the other side of the mark as the receiver is tuned through the signal. Correct tuning is indicated when the pointer is at the meter zero.

Switching from a-m to f-m reception removes the output of the diode detector from the first audio amplifier and connects the output of the discriminator to the first audio amplifier. The a-v-c line also is removed from the diode detector circuit and connected to a bias obtained from the grid circuit of limiter stage V7. In addition to being sensitive to frequency variations, the discriminator is sensitive to amplitude variations. Hence the limiter stage is needed to provide the discriminator with a constant amplitude input. A strong signal causes the limiter to draw grid current on positive peaks and to cut off on negative peaks. The grid current flowing through resistor R39 causes a voltage to be developed across it which is negative with respect to ground. This voltage is fed to the grids of the first two i-f amplifiers. The bias from the limiter may be considered as a-v-c voltage. The discriminator is a conventional Foster-Seeley circuit. Resistor R42 and capacitor C32 form a de-emphasis circuit, which reduces high frequency components introduced at the transmitter.

The local oscillator V15 is a tickler feedback oscillator. The output of this oscillator is capacitively coupled to the cathode of the mixer tube. The oscillator is shunt fed so that plate voltage does not appear on the tuning capacitor.

The beat frequency oscillator V14 is a Hartley oscillator and is used in the reception of c-w signals. The output of the BFO is capacitively coupled to the plate of the diode detector. A small trimmer capacitor C60 is mounted on the front panel of the receiver. This capacitor is used to vary the frequency of the beat note of c-w signals.

A conventional full-wave power supply provides plate,

filament, and regulated voltages to the receiver. The voltage regulator tube V10 must be in the socket before the receiver will operate. An internal jumper in the tube acts as an interlock. Removing the tube from its socket opens the +150-volt circuit. Switch S5, the SEND RECEIVE switch, removes plate voltage from the receiver when it is in the SEND position and prevents operation of the receiver. However, the voltage for the tube heaters is not interrupted.

Socket X2 allows the receiver to be connected to a relay, which automatically disables the receiver when an associated transmitter is keyed. The receiver has also a socket on the rear of the chassis to which either batteries or a vibrator power supply can be connected for portable operation. When the receiver is used on regular power, the shorting plug P1 is inserted into socket X1.

The noise limiter and audio amplifiers are conventional in design. The first audio amplifier and phase inverter V9 provide a push-pull input to the audio output stage. Switch S9 and its associated resistors and capacitors form a tone control circuit. This circuit is omitted in later models of the RBK receiver.

## MODEL RDZ RECEIVER

The RDZ receiver is a superheterodyne receiver designed to receive either voice or m-c-w transmissions in the frequency range from 200 to 400 megacycles. An autotune mechanism in this receiver makes it possible to select any one of ten preset crystal-controlled channels. A photograph of the receiver is shown in figure 8-4. The RDZ receiver and its companion transmitter the TDZ may be controlled with channel selector units installed at several positions remote from the equipment. These selector units make it easy to change the frequency of the receiver and transmitter in a matter of seconds from some remote position.



**Figure 8-4.—Model RDZ receiver.**

### **Preselector and Converter Units**

A schematic diagram of the preselector and converter units is shown in figure 8-5. The antenna transmission line is connected through jack J101 to the inductor in the first tuned circuit. The tuning capacitor is a split stator type which eliminates the need for a rotor brush contact. If the tuning capacitor with rotor brush contacts were used, any variation in rotor brush resistance would result in objectionable electrical noise.

The two sections of the capacitor together with the coil form a balanced bridge circuit in which the r-f voltage between the center tap of the coil and the corresponding midpoint of the capacitor is zero. Grounding the coil at the center tap effectively grounds the capacitor rotor at its corresponding midpoint.

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AVAILABLE**



The center lead of the antenna transmission line connects to a tap on the inductor. The position of the tap is adjusted to obtain an impedance match between the antenna transmission line and the first tuned circuit. The first tuned circuit is connected to a second tuned circuit by a form of link coupling. These two tuned circuits are similar. They improve the image rejection, reduce cross modulation, and improve the overall selectivity characteristics of the receiver.

The end frames of the tuning capacitors are grounded to r-f through a small fixed capacitor. The tuning capacitors of the first two tuned circuits are mounted as one assembly. It would be desirable to ground the frames directly to the chassis. However, if this is done, a wave trap circuit is formed. When the frame is grounded through the capacitor, the resonant frequency of the wave trap is changed to a frequency higher than that of the receiver tuning range and receiver performance is not affected.

The output of the second tuned circuit is coupled to the grid of the r-f amplifier by a coupling capacitor. This capacitor permits isolation of the a-v-c voltage applied to the grid of the r-f amplifier. Without the capacitor the a-v-c voltage would be shorted to ground through the center taps of the inductors.

Low frequency receivers usually have an oscillator whose fundamental frequency beats with the incoming signal to produce the intermediate frequency. The local oscillator of the RDZ is crystal-controlled and operates at a frequency considerably lower than the frequency necessary to mix with the incoming signal. Crystals with frequencies ranging from 4.48 to 7.1 megacycles are used in the oscillator. The crystal selected depends on the frequency of the received signal. The comparatively small frequency range from 222 to 232 Mc is not covered by the RDZ. The third harmonic of the crystals

which would be needed to cover this band is at or near the intermediate frequency. For example, the crystal frequency needed for 226.5 Mc is 5.033 Mc. The third harmonic of this crystal is 15.1 Mc which is also the intermediate frequency. It is therefore possible that the third harmonic of this crystal might block the i-f amplifiers.

The fundamental frequency of the crystal is either tripled or quadrupled in the plate circuit of the oscillator. Following the oscillator are four frequency doubler stages. The crystal frequency is multiplied either 48 or 64 times before being injected into the mixer. The tuned circuits used in the multipliers and in the r-f amplifier are, for the most part, similar to those described for the antenna input circuit.

The midpoint of the rotor plates of the tuned tank capacitor in the oscillator plate circuit is placed at r-f ground potential through rotor brush contacts and capacitor C106. This has been found necessary to prevent parasitic oscillations. Inductor L110 is connected between the center tap of inductor L106 and ground. This inductor together with the distributed capacity of each half of L106 forms a tank circuit with a resonant frequency outside the low-frequency limit of the receiver tuning range. This resonant tank circuit provides greater gain at the low frequencies than would be obtainable with just the tuned tank circuit.

The tuning capacitor of the mixer V106 grid circuit and of the last doubler plate tank are mounted on a common shaft and frame. Between the two sections of the capacitor there is a center frame plate. A small stray capacity exists between the center frame plate and the stator plates of the mixer tuning capacitor. The output of the last frequency doubler is coupled capacitively to the center frame plate and therefore to the mixer by the stray capacity. The output of the last frequency doubler is fed



to the mixer also by mutual inductive coupling between inductors L105 and L106.

The output frequency of the last frequency doubler is 15.1 Mc above the frequency of the incoming signal. The two signals heterodyne in the mixer to produce the intermediate frequency which is developed across the tuned circuit in the plate circuit of the mixer. Usually the first i-f transformer is connected in the plate circuit of the mixer, but in the RDZ this is not possible due to the mechanical layout. The i-f signal is coupled to a terminal strip through capacitor C119 and then into the i-f/a-f unit.

### Tuning

The tuning dial on the RDZ is calibrated in frequency. However, the dial calibrations are not sufficiently accurate for tuning the receiver. A system is incorporated whereby the excitation voltage of the frequency multipliers following the crystal oscillator is measured. The multiplier tuning switch, S101A, connects a grid leak bias developed in each switch position to the a-v-c bus.

The switch, as shown in figure 8-5, is in the RECEIVE position. Placing the switch in position 3 connects the a-v-c bus to the grid of the fourth frequency doubler stage, V105. Switch S101B removes the ground from the common connection of resistor R109, resistor R110, and capacitor C114. Grid current and grid excitation of the fourth doubler will be maximum when the tank circuit in the plate of the third frequency doubler is tuned to resonance. The grid current causes a voltage to be developed across the additional resistor R109 placed in the circuit by switch S101B. This voltage will be maximum when the tuning is correct for that particular frequency.

The arrangement is the same for the other two positions of the multiplier tuning switch. The bias developed in each position of the switch is connected to the a-v-c

bus. When no signal is being received the input meter of the receiver indicates zero. However, if a signal is received, an a-v-c voltage is developed and the input meter provides an indication of the signal strength. When S101 is in positions 1, 2, or 3, the negative bias from successive multiplier stages is applied to the receiver input meter through the a-v-c bus connection. Correct tuning of the multiplier stages is indicated by a maximum reading on the meter. The input meter switching arrangement is a very useful servicing aid whenever trouble develops in the multiplier section.

### I-F Amplifiers

The output of the mixer is coupled to the first i-f amplifier and also to the scanning amplifier. The scanning amplifier is a cathode follower and may be used to supply a portion of the i-f signal to a panoramic adaptor. The i-f amplifiers are conventional circuits except that the second, third, and fourth stages have transformers with variable coupling and therefore variable selectivity. The secondary windings of these i-f transformers are connected to a mechanical linkage and a shaft. Turning the shaft rotates the secondary windings with respect to the primary windings, thereby changing their coupling. The different stages are aligned by powdered iron slugs. A separate slug is used for each primary and each secondary winding. Five stages of i-f amplification are used in the RDZ receiver. The output of the fifth i-f amplifier is coupled to the diode detector.

### Input Meter Circuit

A simplified schematic diagram of the input meter circuit is shown in figure 8-6. The meter is in the middle arm of a bridge circuit. Switch S201A removes the r-f gain control R204 and S201C connects the meter to the

voltage divider. Potentiometer R257 is used to balance the bridge with no signal input to the receiver. If the voltage drop across the cathode resistor R219 is equal to the voltage between the potentiometer arm and ground, the bridge is balanced and no current flows through the meter. When a signal is received, a-v-c voltage is applied to the grid of V204. The a-v-c voltage acts as bias voltage

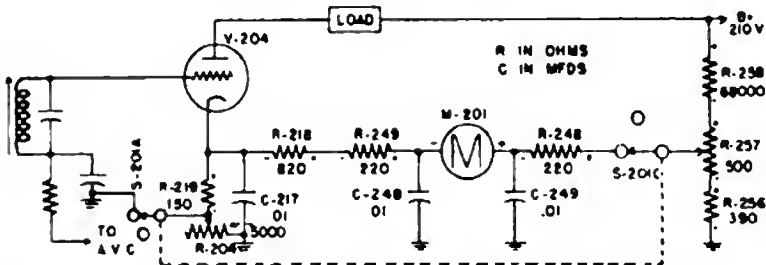


Figure 8-6.—Simplified schematic diagram of the input meter circuit.

and reduces the current and voltage drop through the cathode resistor. This unbalances the bridge and current flows through the meter. The polarity of the voltage drops caused by this current is shown on the diagram. The

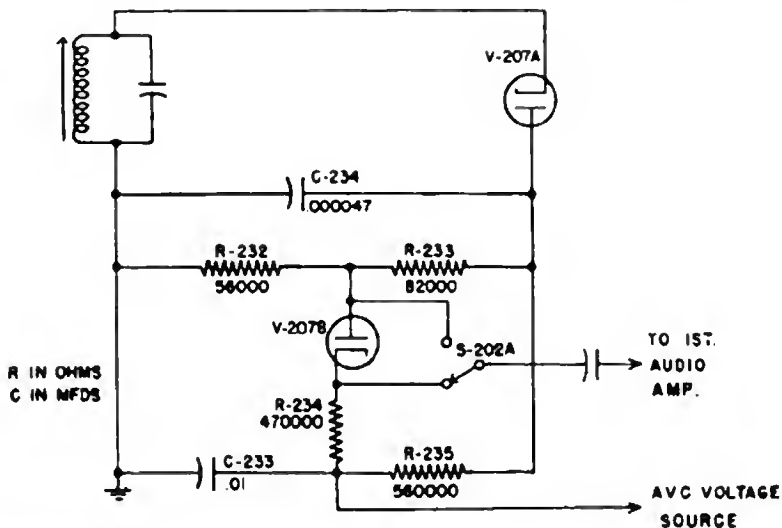


Figure 8-7.—Simplified schematic diagram of the diode detector and noise limiter.

amount of current depends on the a-v-c voltage. The stronger the signal, the greater the a-v-c voltage, the greater the bridge unbalance, and the greater the meter reading.

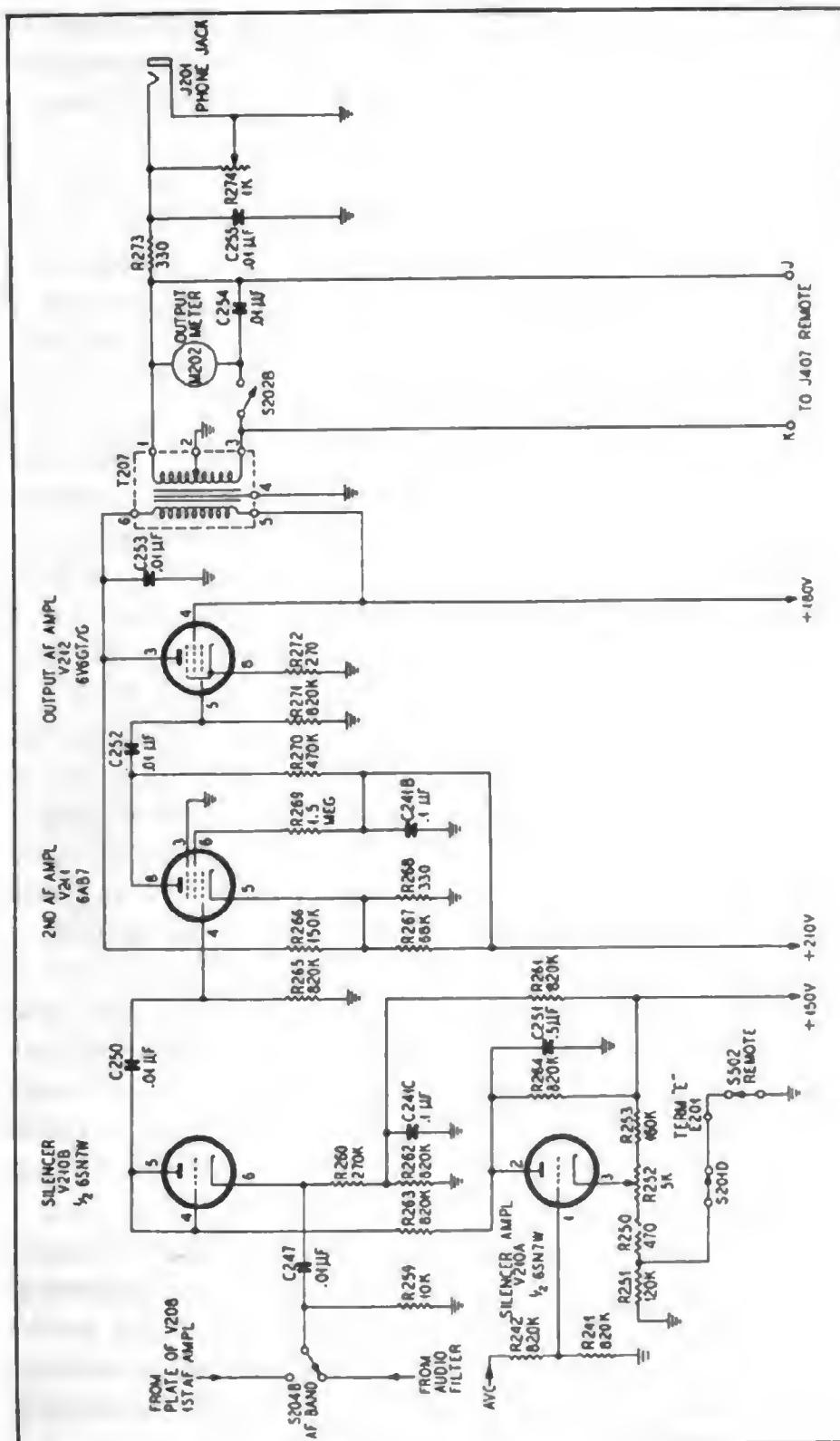
### **Detector and Noise Limiter**

A simplified schematic diagram of the diode detector and series noise limiter is shown in figure 8-7. The detector V207A is conventional in design. The noise limiter cathode is connected to the a-v-c line, which is negative with respect to ground. The plate of the limiter is connected to the common connection between the diode load resistors. When a normal signal is detected, the plate also is at a negative potential with respect to ground. However, the plate is less negative than the cathode and the diode conducts. This provides a continuous circuit through the limiter and S202A to the first audio amplifier.

If a sudden burst of noise comes through the receiver, a large negative potential is applied to the plate of the limiter diode. The cathode cannot follow this sudden change because of the long time constant of the a-v-c circuit. The plate is now negative with respect to the cathode and the diode ceases to conduct. This prevents the noise from entering the audio amplifiers. The point at which the diode begins limiting the signal is adjusted automatically to the strength of the received signal. The weaker signals are limited with less noise and the stronger signals with more noise because of the action of the a-v-c voltage. Thus a weak signal is cut off for a small amplitude noise pulse; whereas a strong signal is not cut off by the same amplitude of noise pulse.

### **Silencer Circuit**

The silencer of the RDZ disables the receiver during periods when no signals are being received. A schematic diagram of the silencer circuit is shown in figure 8-8.



The silencer tube V210B is a diode-connected triode in series with the audio supply to the second audio amplifier. The silencer amplifier acts as a control tube for the silencer.

The voltage on the silencer plate is positive with respect to ground and is supplied from the silencer amplifier plate through resistor R263. The voltage on the silencer cathode also is positive with respect to ground and is supplied from the +150-volt source through a voltage divider network comprising resistors R261 and R262. With no input signal the silencer amplifier control potentiometer R252 is adjusted until the silencer amplifier draws enough plate current to reduce its plate voltage and that of the silencer plate to a value below that of the silencer cathode. Thus when the silencer plate voltage becomes negative with respect to the cathode, conduction ceases and the silencer cuts off. The output to the audio amplifiers is reduced to zero and the receiver is mute.

The grid of the silencer amplifier is connected to the a-v-c line. When a signal enters the receiver, the negative a-v-c voltage is applied to the grid of the silencer amplifier thereby reducing its plate current and increasing its plate voltage and that of the silencer. When the increasing silencer plate voltage becomes positive with respect to the silencer cathode, the tube conducts and the signal is transmitted to the audio amplifiers. It is important that the silencer control (R252) be correctly adjusted. Otherwise, with the silencer amplifier bias too low, a weak signal, which develops low a-v-c voltage, would not cause the silencer to conduct and the receiver would remain mute.

The output of the silencer is coupled through a capacitor to the grid of the second audio amplifier. Degenerative feedback is applied from the output amplifier to the cathode of the second audio amplifier through resistor R266. The feedback keeps the audio output of the receiver

constant as the load changes across the output transformer. One-half the output transformer winding is connected to the phone jack on the front of the receiver. The full winding supplies audio voltage to remote stations.

A photograph of the RDZ with the front cover removed is shown in figure 8-9. The receiver is tuned by first selecting the desired channel. Then the wing nut on the main dial is loosened. This engages the tuning knob. The

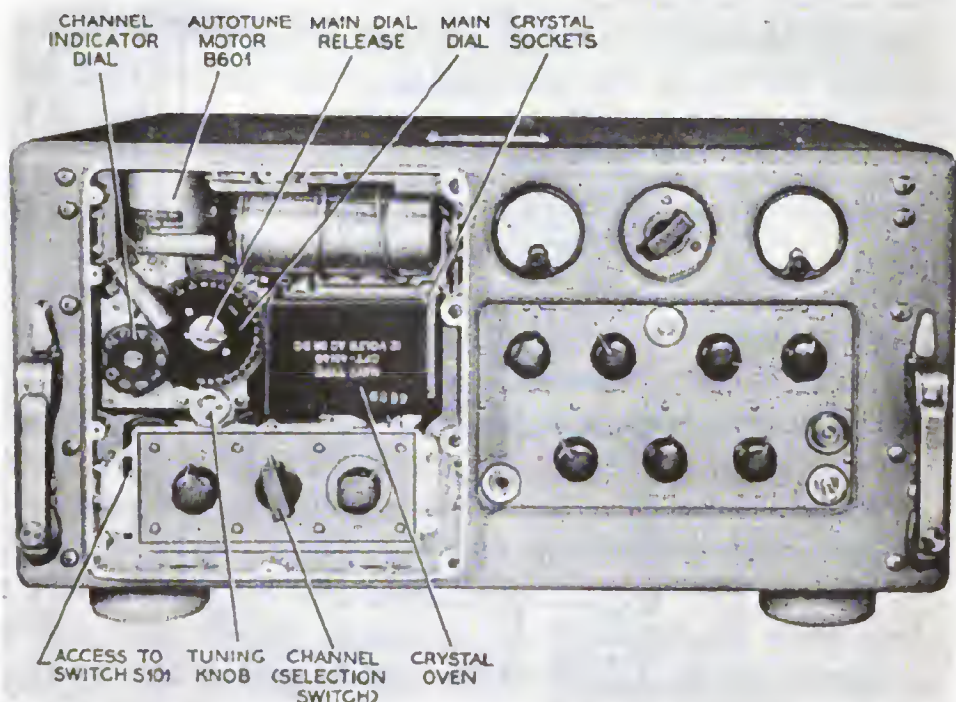


Figure 8-9.—RDZ with the front cover removed.

multiplier tuning switch S101 (figure 8-5) is turned to each of its positions and the receiver tuning knob is adjusted for maximum indication on the input meter. Note that S101 is operated by inserting a screw driver through the opening indicated at the lower left in figure 8-9. This procedure is carried out for each of the ten channels.

The diagram illustrates the control circuit for a motor-driven device, featuring the following components and connections:

- Power Source:** A 22.50V supply is connected to the circuit.
- Control Switches:**
  - STOPPING RACKET:** A switch that controls the motor's operation.
  - STOPPING CAM:** A cam switch that controls the motor's operation.
  - RELAY ARM:** A switch controlled by the motor's operation.
  - STOPPING CAM:** A cam switch that controls the motor's operation.
  - STOPPING RACKET:** A switch that controls the motor's operation.
  - STOPPING CAM:** A cam switch that controls the motor's operation.
  - STOPPING RACKET:** A switch that controls the motor's operation.
- Motor:** A motor that drives the mechanical components.
- Relay:** A relay that controls the motor's operation.
- Cam:** A cam that controls the motor's operation.
- Spring:** A spring that provides tension to the mechanical components.
- Wiring:** The circuit is connected to a 22.50V supply and includes various control lines.

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## Autotune System

The RDZ receiver incorporates an autotune system of channel frequency selection by means of which the pre-selector and converter stages are quickly tuned to the desired channels. By operating the channel selector switch on the receiver or at a remote operating position, any one of 10 fixed channel frequencies can be obtained.

The autotune unit is housed in a metal casting behind the main dial and the channel indicator dial. A simplified schematic diagram of the autotune system is shown in figure 8-10. When the channel selector switch is turned to the desired channel, with the local-remote switch in the local position, relay K601 is energized through seeking switch S604. When this relay operates, it applies 110 volts a-c to motor B601. The motor drives the various mechanisms of the autotune system.

The system as shown in the schematic is at rest on channel 6. Relay K601 is deenergized because S604 is open on channel 6. Suppose that the channel selector is changed to channel 7. The circuit to K601 is now completed from terminal 16 of E605, through the channel selector switch, the seeking switch S604, and the normally closed contacts controlled by the motor stopping cam to the other side of the 110-volt line at terminal 15.

When relay K601 is energized, its contacts close and complete the circuit to the motor. One pair of contacts associated with relay K601 acts as a holding circuit. These contacts keep relay K601 energized after the motor stopping cam begins to rotate. Energizing K601 allows the relay arm to disengage the stopping ratchet. This permits the stopping ratchet, the cam drum, the crystal switch, the motor stopping cam, the seeking switch, the stop ring drum, and the main tuning capacitor to rotate.

The motor turns the seeking switch to channel 7 and K601 is deenergized. However, the motor continues to rotate because of a parallel path which was completed

to the motor when the stopping cam began to rotate. With K601 deenergized, the relay arm engages the stopping ratchet through a mechanical linkage. This stops the crystal switch, the channel dial, the stopping ratchet, the cam drum, and the seeking switch.

The detent in the cam drum is now aligned with the pawl for this particular channel. The motor stopping cam, the main dial, main tuning capacitor, and stop ring drum are still turning. They continue to turn until the detent in the stop ring drum becomes aligned with the

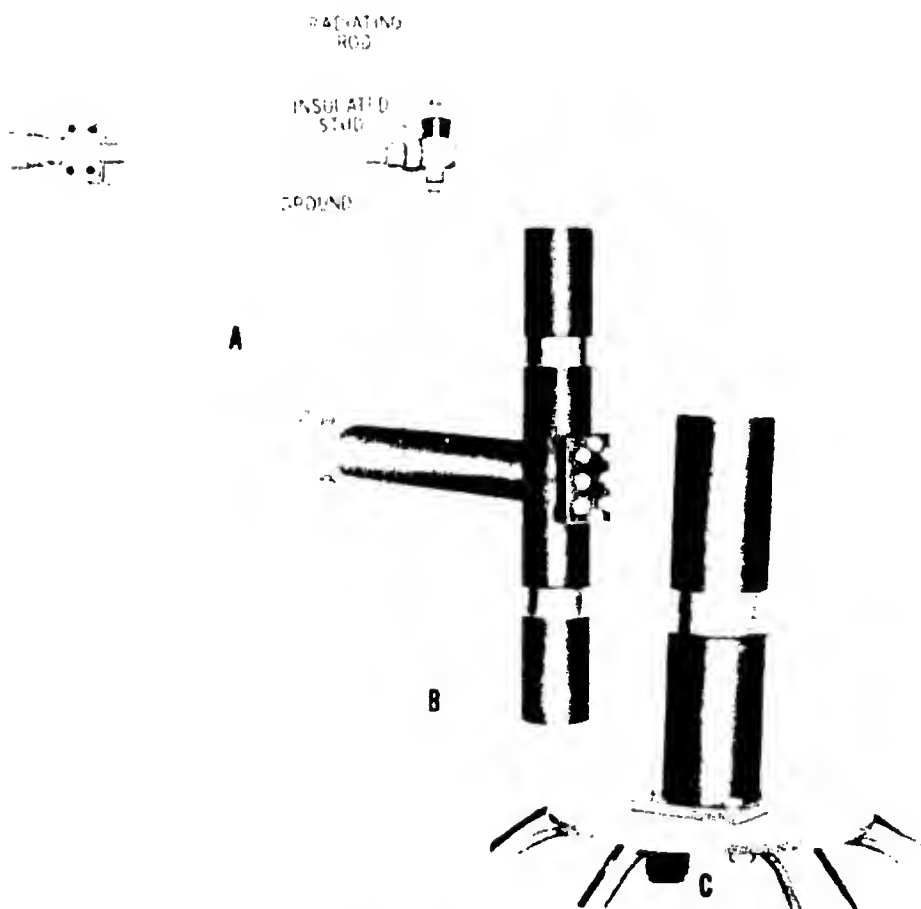


Figure 8-11.—Antennas used with RDZ receiver. A, Navy type 66147, B, antenna AT-150/SRC, C, antenna AS-390/SRC.

other end of the pawl. At this time a spring pulls the end of the pawl into the detent, and the main tuning capacitor and stop ring drum stop turning. Friction clutches allow the motor to keep rotating. The motor is stopped by the motor stopping cam which continues to rotate until its associated contacts open and break the circuit to the motor.

### **Antennas**

Three different types of antennas are available for use with the RDZ receiver. A photograph of the antennas is shown in figure 8-11. The most commonly installed antenna is type 66147 (figure 8-11,A) which is a vertical dipole. It has an impedance of 50 ohms and covers the entire frequency band from 200 to 400 Mc. The antenna AT-150/SRC (figure 8-11,B) is used when the antenna has to be installed below the superstructure of a ship. The antenna AS-390/SRC (figure 8-11,C) is an unbalanced broad band antenna used in installations where the antenna is mounted above all other antennas and above the superstructure of the ship.

### **QUIZ**

1. What is the frequency range of the RDZ receiver?
2. How is stable operation of the frequency converter in the RDZ receiver accomplished?
3. What is the frequency range of the RBK receiver?
4. What parts of the RBK receiver are common to both a-m and f-m reception?
5. What types of detectors are used in the RBK receiver?
6. In the RBK three-band receiver how are the coils not in use connected?
7. How is the band-pass characteristic increased in the i-f amplifiers of the RBK receiver?
8. How is RBK receiver gain held constant when the band pass of the i-f stages is increased?

9. What is the relationship between bandwidth, coupling, and gain of the i-f stages?
10. How is the strength of a-m signals measured in the RBK receiver?
11. How is the signal strength meter connected for use as a tuning indicator for f-m signals?
12. How does the indicator meter respond as an f-m signal is tuned in?
13. What is the function of the series resistor and the shunt capacitor between the discriminator and the first audio amplifier in the RBK receiver?
14. What feature of the tuning capacitors in the RDZ receiver eliminates the need for a rotor brush contact?
15. How is the rotor of the tuning capacitors in the RDZ receiver placed at r-f ground potential?
16. Why are the end frames of the tuning capacitors grounded through a capacitor rather than directly to the chassis in the RDZ receiver?
17. Why is the frequency range from 222 to 232 Mc not covered by the RDZ receiver?
18. How many times is the fundamental frequency of the crystal multiplied in the converter before being injected into the mixer of the RDZ receiver?
19. Across what part of the mixer is the i-f signal developed in the RDZ receiver?
20. How is accurate tuning accomplished in the RDZ receiver?
21. How is selectivity of the second, third, and fourth i-f stages of the RDZ receiver changed?
22. How many i-f stages are used in the RDZ receiver?
23. What adjustments are provided for alignment of the i-f stages?
24. How is noise limited in the RDZ receiver?
25. What is the function of the silencer circuit in the RDZ receiver?
26. What is the purpose of degenerative feedback from the output amplifier to the cathode of the second audio amplifier in the RDZ receiver?

## **RADIO DIRECTION FINDERS**

### **PRINCIPLES OF RDF**

Before the development of radar and loran, radio direction finders provided the only electronic means of obtaining a position at sea. A ship entering port or steaming along the coast near a direction finder station had two ways of obtaining a fix.

By the first method a ship would call a radio direction finding station on shore and request a position. Then the ship would send a series of dashes while receiving stations on the shore were taking bearings. The receiving stations would communicate with one another by telegraph or telephone. One station would collect the several different bearings and plot them on a chart, determine the ship's position, and then send it to the ship.

By the second method a ship would take several bearings on beacons or known radio stations and plot these bearings on a chart to obtain a fix. The radio direction finder is not as important today as it was before the development of radar and loran. It still plays an important role in the navigation of aircraft. However, other devices are rapidly taking the place of radio direction finding.

Essentially the radio direction finder is a sensitive receiver to which a directional antenna is connected. Range information is not obtained with just one bearing

alone. By taking bearings on at least two transmitters a position can be obtained. The first installations had antennas which were rotated by hand to obtain a bearing. Later, the BELLINI-TOSI antenna was developed, which does away with the rotating antenna. The Bellini-Tosi antenna consists of two fixed loops mounted at right angles to each other.

Most direction finders operate in the low- and medium-frequency bands. Bearings are accurate only when the radio waves travel in a straight line from the transmitter to the loop. This means that only a ground wave is useful for obtaining an accurate bearing. Increasing the frequency reduces the area covered by the ground wave. Bearings obtained from sky waves are not reliable. Several factors affect the accuracy of bearings. Those discussed in this chapter include antenna effect, night effect, and deviation. The first essential part of the radio direction finder is the antenna, which in most cases is a small loop.

## LOOP ANALYSIS

A transmitted wave consists of two components—the electric field and the magnetic field. One cannot exist without the other. The two components and the direction of propagation are mutually perpendicular.

Polarization of an electromagnetic wave is expressed in terms of the position of the electric field. If the electric field is vertical, the wave is said to be vertically polarized. Many low and medium frequency transmitting antennas are vertical and, therefore, radiate a vertically polarized wave. The magnetic field is at right angles to the electric field and is parallel to the surface of the earth for the vertically polarized wave.

Radio direction finding makes use of the magnetic field component of the radio wave by providing a metallic shield around the loop. The shield has an insulated segment which prevents it from acting as a shorted turn. A

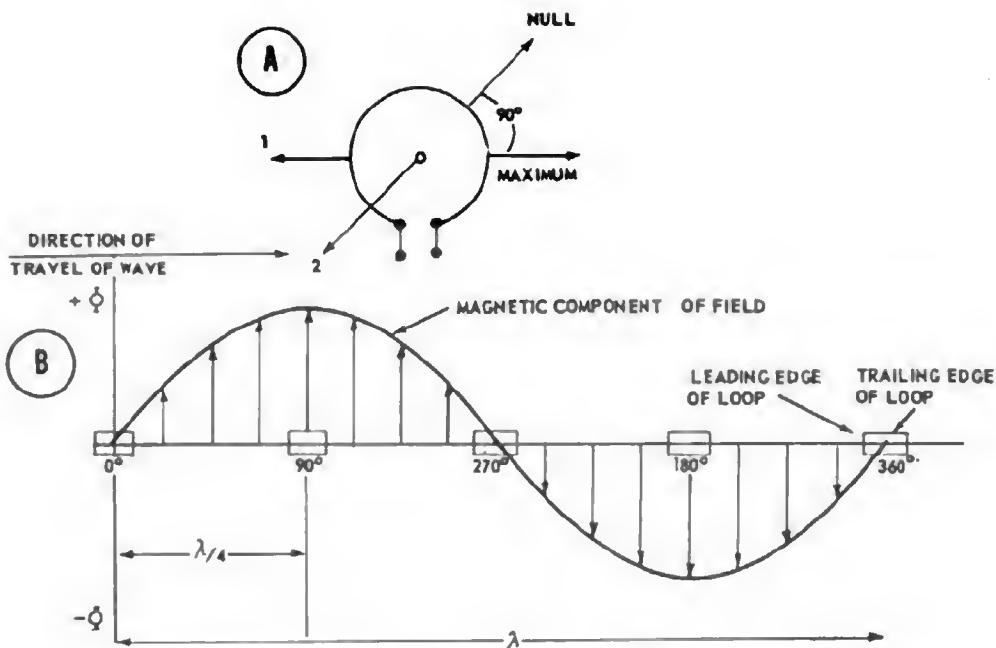


Figure 9-1.—Loop antenna analysis. A, Maximum and null, B, generation of loop voltage.

simple loop is indicated in figure 9-1,A. The loop is small compared to the wavelength corresponding to the operating frequency. Some loops operating on a frequency below 500 kilocycles are less than 1 foot in diameter.

Maximum signal voltage is induced in the loop when the plane of the loop is parallel to the direction of travel of the wave. This is the case when travel is along line 1 in figure 9-1,A. In this position, the loop is edgewise with respect to the line of travel and contains the maximum number of flux linkages. If the line of travel is  $90^\circ$  away from the position indicated along line 1, the plane of the loop is perpendicular to the direction of travel of the wave. This is the case when travel is along line 2. In the latter position no flux links the loop and the induced voltage is zero. The loop is broadside with respect to line 2. Hence, no signal is fed to the receiver and the loop is said to be at a null.

An analysis of the voltage induced in a loop antenna

for the position of maximum signal is shown in figure 9-1, B. The sine curve represents the magnetic field intensity as the wave moves through the loop at the speed of light in a horizontal direction from left to right. Five loop positions are shown at  $90^\circ$  intervals (a quarter wavelength apart) as plan views to indicate instantaneous voltages.

At the  $0^\circ$  position, the voltage induced in the loop is a maximum because the rate of change of the flux is greatest and the voltage induced in the leading and trailing edges are in series addition. In the  $90^\circ$  position, the voltage induced in the loop is zero because the rate of change of the flux linking the loop is zero. (The voltage components in the leading and trailing edges are in series opposition.) At the  $180^\circ$  position, the loop voltage is again maximum, but of reverse polarity. This is true because the components in the two edges of the loop reversed their polarity with respect to the  $0^\circ$  position.

At the  $270^\circ$  position, the voltage is again zero. At the  $360^\circ$  position, the voltage induced returns to a maximum with the same polarity which existed at  $0^\circ$ . From this analysis, it is evident that the voltage induced in the loop, as a result of the passage of the magnetic component of the radio wave, is an a-c voltage with a sine waveform. The induced voltage is displaced from the magnetic component of the field by  $90^\circ$ .

## DIRECTIONAL CHARACTERISTICS

The directional characteristics of a loop antenna are shown in figure 9-2. The tangent circles represent the locus of all the ends of the loop output voltage vectors drawn from the point of tangency for various angles of arrival of the radio wave with respect to the plane of the loop. The horizontal rectangle at the center of the diagram represents the top view of the loop antenna. The pattern is a figure of revolution whose axis is perpendicu-



lar to the plane of the loop. This axis represents the line of zero output voltage.

Maximum loop output voltage occurs when the line of travel of the magnetic component of the radio wave is in a horizontal direction and parallel to the plane of the loop. The figure eight pattern indicates that there are two nulls—one in the direction indicated at *A*, the other at *B*. The pattern also indicates that there are two maximums—one in the direction indicated at *C*, the other at *D*. A rotation of the loop through  $180^\circ$  causes a reversal of the phase of the output voltage.

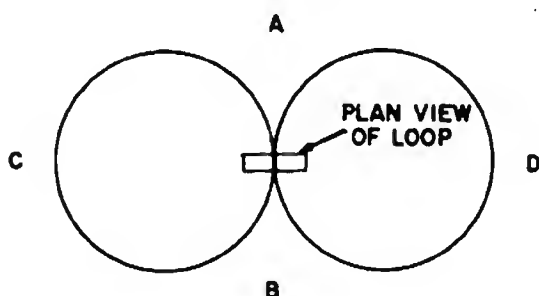


Figure 9-2.—Directional characteristics of a loop antenna.

In most cases the radio wave is modulated and the strength of the loop voltage is measured in terms of the magnitude of the audio output of the receiver. The directivity pattern of figure 9-2 shows that a relatively large rotation of the loop produces only small changes in the loop voltage in the vicinity of maximum signal. A bearing taken by means of the maximum signal is therefore broad. Furthermore, the response of the ear is logarithmic rather than linear and small changes in the magnitude of a loud signal are not easily detected. For these reasons a loop bearing is not taken by judging the point of maximum signal.

Usually a loop bearing is taken by means of a null. Relatively large changes in loop voltage per degree of loop rotation occur in the vicinity of a null position. The

ear is more sensitive to large changes in the output voltage of the receiver. For this reason the null method is preferred.

The magnetic field of the radio wave is assumed to be varying in space and time according to the sine curve (figure 9-3,A). Assume the loop to be oriented for maxi-

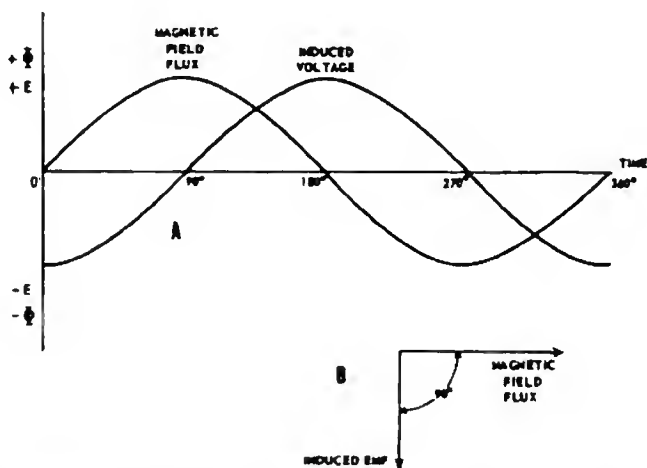


Figure 9-3.—Relation between flux and induced voltage.  
A, Sine curves, B, vectors.

mum output voltage. As the magnetic flux lines of the radio wave cut the loop, a voltage of sine waveform is induced in the loop. The instantaneous values of this voltage depend on the rate of change of flux linking the loop. At the instant the flux is maximum, its rate of change is zero. Hence, the loop voltage is zero. A quarter cycle ( $90^\circ$ ) later, the flux is going through zero and changing at its maximum rate. Therefore, the loop voltage is maximum.

The induced voltage in the loop, like the induced voltage in a transformer, obeys Lenz's law which states that all induced voltages oppose the force that produces them. Thus, in the first quarter cycle ( $0^\circ$  to  $90^\circ$ ) the field is rising in a positive direction and the induced voltage is negative, opposing the rise. In the second quadrant ( $90^\circ$

to  $180^\circ$ ) the flux is falling and has a positive polarity, whereas the induced voltage in the loop is seen to lag the magnetic field component of the radio wave by  $90^\circ$  (figure 9-3, B).

### Disadvantages of a Simple Loop

The simple loop (figure 9-4, A) has several disadvantages and is never used in actual installations. The first

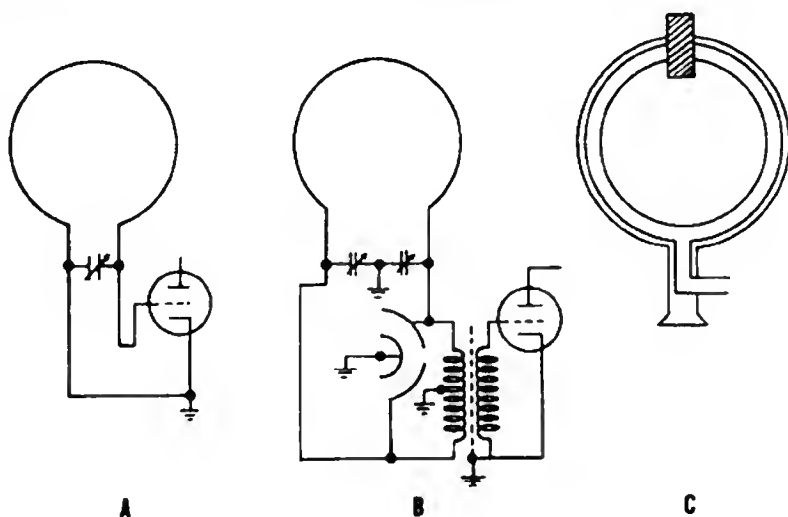


Figure 9-4.—Loop antennas. A, Simple loop, B, balanced loop, C, balanced loop with an electrostatic shield.

objection is that the loop is unbalanced with respect to ground. The vertical sides of the loop act as simple vertical antennas and, even though the loop is turned  $360^\circ$ , a null cannot be obtained. Some signal will always be developed in the antenna. Hence, without a balance, only a position where the signal is minimum can be obtained. This position is not well defined and, if steps are not taken to balance the loop, the bearings will be inaccurate. This condition is called ANTENNA EFFECT.

Figure 9-4,B shows a loop with a balanced input and also a balance control to compensate for any small

changes in the circuit. The balance control grounds the voltages induced in the vertical arms of the loop by the electric component of the radio wave. This is accomplished by capacitive coupling between the vertical arms and ground. For a given loop position the balance control equalizes these induced voltages. Even this arrangement is not very satisfactory because, if the balance control is adjusted, the loop is detuned from resonance, since the balance control is in parallel with the loop tuning capacitor.

Another disadvantage of the simple loop is that, when it is balanced and then rotated to another position, it becomes unbalanced because the capacity which exists between the loop and surrounding objects changes. Using a balanced shielded loop (figure 9-4,C) eliminates the disadvantages of a simple loop. The shield is broken at the top with an insulated washer and grounded. This insures that the capacity from the loop to ground remains constant, irrespective of its position. The insulated washer prevents the shield from acting as a shorted turn. If the shield acted as a shorted turn, the inductance of the loop would be lowered. The shield also prevents the electric field component of the transmitted wave from affecting the loop voltage. It can be compared to the Faraday shield used in transformers.

### Quadrature Effect

Any closed loops in the vicinity of the loop will cause deviation of the null. Closed loops may be formed by guys, lifelines, masts, superstructure, or radio antennas. The resonant frequency of any loops formed by the different parts of a ship is usually well above the direction finder frequency. These loops have a voltage induced in them by the same signal which induces a voltage in the direction finder loop. They reradiate this signal which in turn

cuts the direction finder loop to produce spurious voltages therein.

The effect of the reradiated fields is known as QUADRATURE EFFECT. The phase of the reradiated signal is usually random but may be resolved into two parts—that component of voltage in phase with the direction finder loop voltage and that component of voltage  $90^\circ$  out of phase with the loop voltage. The component  $90^\circ$  out of phase with the loop voltage may be balanced out with the balance control. The voltage in phase with the loop voltage must be balanced out by the loop itself. This causes the null to be displaced from the position at which it should appear.

The displacement of the null is called DEVIATION. It can be reduced, but cannot be entirely eliminated. When the direction finder is calibrated, a deviation curve is drawn. This is a graph on which deviation is plotted against the bearing to which the antenna is turned. After the loop is calibrated, the operator applies the correction to the bearings observed and obtains a corrected bearing. A small amount of deviation is not objectionable, but any change in the deviation after calibration is objectionable. The deviation will change, if the booms and other structures are not in the same position they occupied when the direction finder was calibrated.

If preliminary tests show that the deviation effect exceeds  $20^\circ$ , steps must be taken to reduce the deviation to a reasonable amount. This is done by placing the direction finder loop inside a large loop as shown in figure 9-5. The compensating loop is usually constructed of large diameter copper wire and strung between the superstructure and a mast to form a closed loop.

The same reradiated fields cut both the direction finder loop and the compensating loop. The resulting induced current in the compensating loop causes a field to be reradiated which is in phase opposition to the reradiated

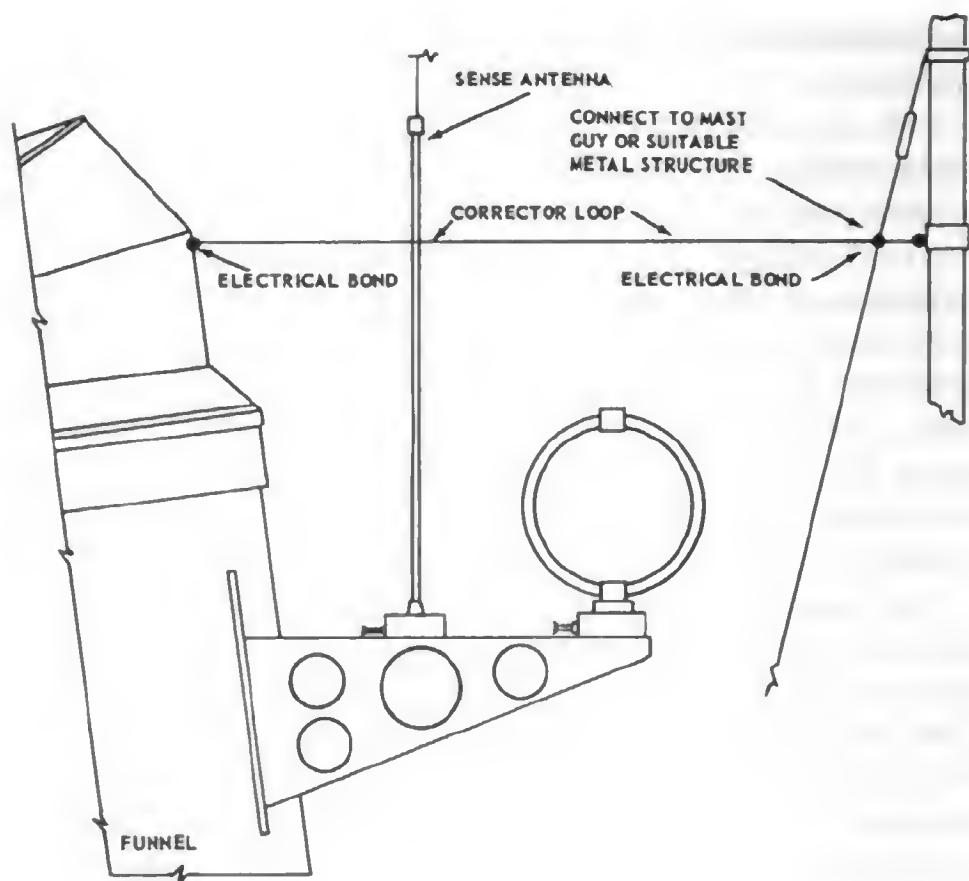


Figure 9-5.—Corrector loop.

fields which cut the direction finder loop. The reradiated field from the compensating loop reduces the magnitude of the quadrature effect and the resulting deviation.

### Night Effect

So far it has been assumed that the magnetic field of the radio wave is parallel to the surface of the earth. This is true for many low frequency signals. It is possible for the polarization of the wave to change by refraction in the ionosphere. This is called **POLARIZATION ERROR** or **NIGHT EFFECT**.

If the transmitted wave is reflected in such a way that

the magnetic field cuts only the horizontal arms of the loop, a figure eight pattern results. It is displaced exactly  $90^\circ$  from the figure eight pattern obtained when the magnetic field cuts only the vertical arms. This is true because the direction of propagation of the refracted wave is not perpendicular to the axis of rotation of the loop.

A sky wave with its magnetic vector at such an angle that the magnetic field cuts both the horizontal and vertical arms of the loop causes the pattern to be displaced at some angle less than  $90^\circ$ . When sky waves are present, the error introduced can range from  $0^\circ$  to  $90^\circ$ .

During the presence of night effect, several conditions may exist. There may be (1) several minima which are steady, (2) a null which may be shifting rapidly, (3) no null at all, or (4) a steady null which can be displaced as much as  $90^\circ$  from the correct bearing. Little can be done about night effect except to know that it is present. The bearings obtained during this time usually are inaccurate. Night effect is most pronounced at sunrise and sunset, since this is the time when the layers of the ionosphere are changing rapidly.

### Balancing the Loop

It was stated earlier that the signal induced in the loop, when the vertical arms of the loop act as ordinary vertical antennas, could be balanced out by balancing the capacity of both sides of the loop to ground. This method of balance has the disadvantage of affecting the tuning of the loop. In later model direction finders, instead of balancing the capacity, a voltage  $180^\circ$  out of phase with the voltage caused by antenna effect is added to the output of the loop. This method of balance does not affect the loop tuning appreciably.

The balancing arrangement used in certain direction

finders is shown in figure 9-6. The voltage induced in the vertical antenna is in phase with the voltage induced in the loop due to antenna effect. By transformer action, the polarity of the voltage coupled from the vertical antenna to the output of the loop can be reversed and made  $180^\circ$  out of phase with the voltage induced due to antenna effect. The voltage to be balanced out appears across L1 and L2. Three conditions may exist. The voltage across L1 may be greater than that across L2, the voltage across L2 may be greater than that across L1, or the voltage across L1 and L2 may be equal. In this last condition the loop is balanced.

The coupling between L2 and L3 is variable. Varying the coupling between the two coils varies the amplitude of the balancing voltage. Also, depending on the position of the two coils, the voltage induced in L2 by L3 may be made either to oppose or to aid the voltage across L2. With L3 in the position shown in figure 9-6, the flux from L3 does not link L2 and no balancing voltage is induced across L2.

The vertical antenna used to obtain the balance voltage acts also as the sense antenna. Introducing a sense voltage into the loop changes the bilateral pattern of the loop

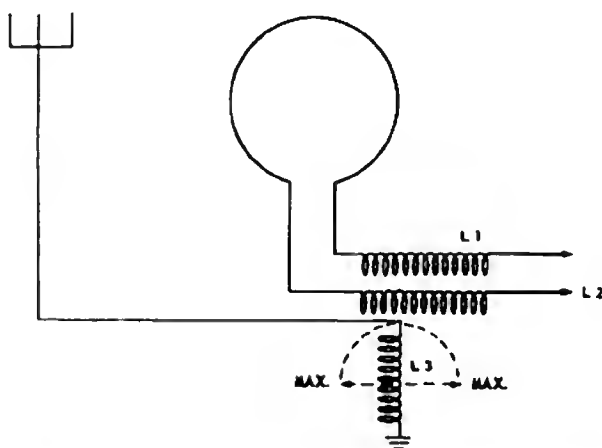
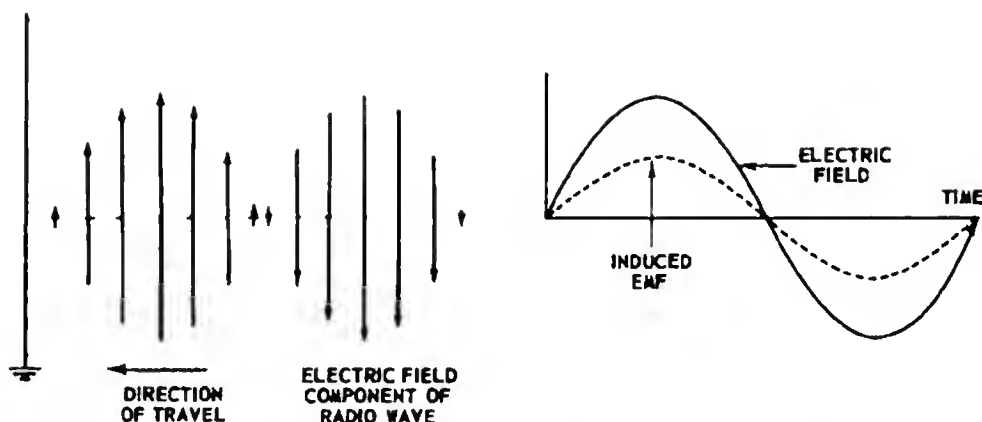


Figure 9-6.—Method of introducing balance voltage into the loop circuit.





**Figure 9-7.—Voltage induced in a vertical antenna by electric field component of a radio wave.**

to a unilateral pattern. It allows the operator to determine which null is the one in the direction of the transmitting station.

### **Use of Sense Antenna**

A simple vertical antenna, as shown in figure 9-7, has no directional effect. The induced voltage in the antenna is caused by the electric component of the transmitted wave and is in phase with the electric field. When the electric field is maximum, the induced voltage is maximum. The two components of the transmitted wave, the electric and magnetic fields, are in phase. Hence, the induced voltage in the antenna is in phase with the magnetic field component. This is not true of the voltage induced in the loop by the magnetic component.

The induced voltage in the loop caused by the magnetic field is  $90^\circ$  out of phase with the magnetic field. Comparing the voltage induced in the loop and that induced in the simple vertical antenna shows that the induced voltage in the loop is  $90^\circ$  out of phase with the induced voltage in the simple vertical antenna. This fact is important in determining which null position of the loop is the actual bearing of a station.

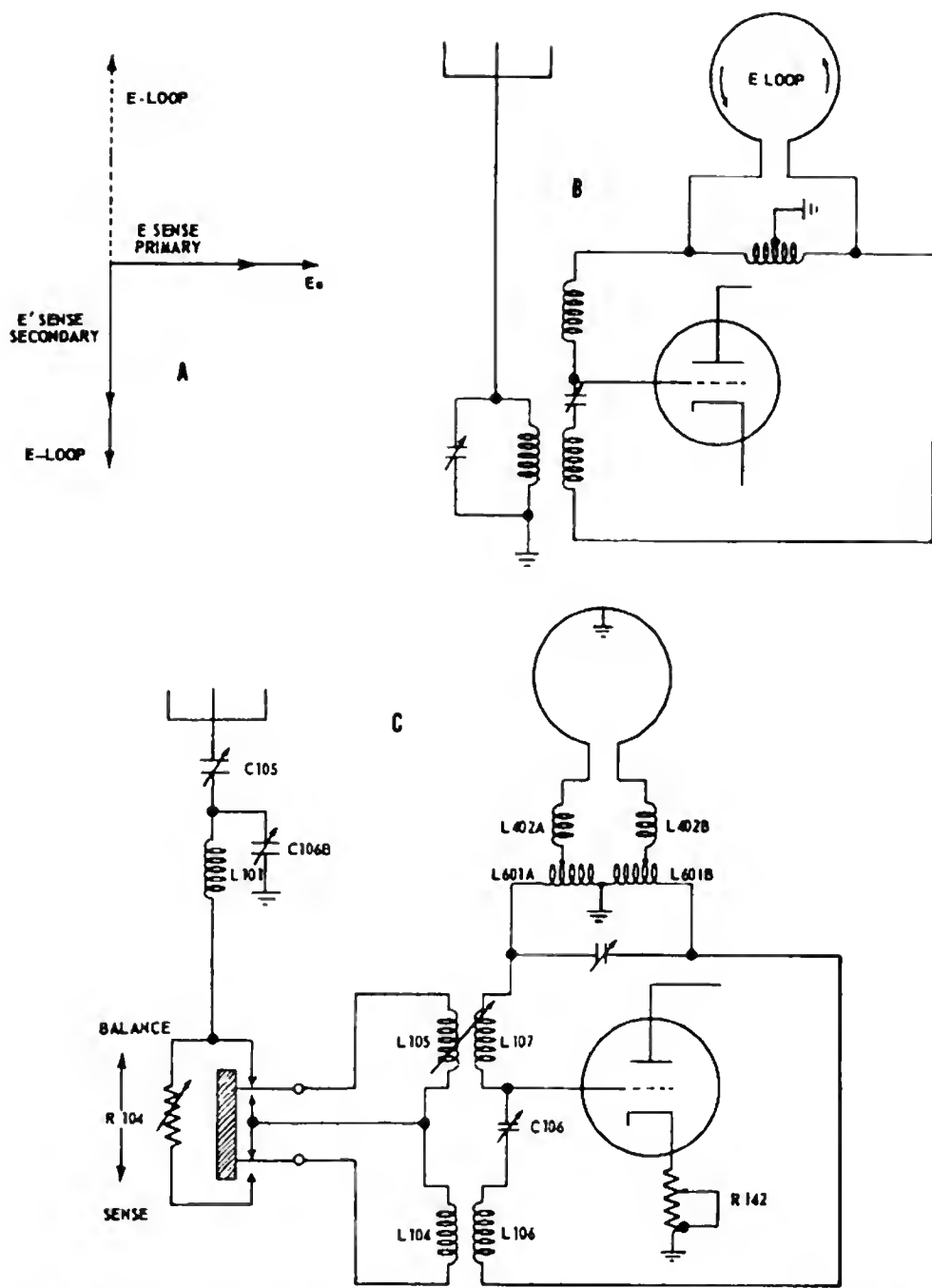


Figure 9-8.—Introducing sense voltage into the circuit. A, Vector diagram of sense voltage and loop voltage; B, simplified circuit; C, schematic diagram of the loop circuit of a model DP-13 direction finder.

The only difference between the two maximum indications of the loop is the reversal in instantaneous polarity of the differential voltage induced in the loop by the magnetic component of the transmitted wave as the loop is rotated through  $180^\circ$ . This reversal in instantaneous polarity is the basis for determining which null is the one toward the transmitting station. The vector diagram in figure 9-8,A, shows the addition of the "sense" and loop voltages to determine the correct bearing.

The voltage induced in the sense antenna is in phase with the transmitted wave and  $90^\circ$  out of phase with the differential voltage in the loop. The transformer that couples the sense voltage to the circuit containing the loop (figure 9-8,B) has a tuned primary and a tuned secondary. Inductively coupled circuits having the primary and secondary windings tuned to resonance, have a  $90^\circ$  phase shift between the primary and secondary voltages. Thus, the secondary voltage induced in the loop circuit from the sense antenna is shown  $90^\circ$  out of phase with that in the primary.

The sense voltage across the tuned loop circuit is either in phase with or  $180^\circ$  out of phase with the differential voltage. Assume that the loop is positioned for maximum differential voltage, that the sense voltage is applied to the loop, and that the two voltages are in phase. The voltages add. This increases the output of the loop voltage. Now, if the loop is rotated  $180^\circ$  to the other maximum point, the phase of the differential voltage shifts  $180^\circ$  with respect to the sense voltage across the second tuned circuit. The sense voltage cancels the differential voltage, if the two voltages are equal in magnitude.

In practice the loop is positioned for a null and the sense button (figure 9-8,C) is depressed. Rotating the loop in one direction causes the output of the direction finder receiver to increase. Rotating the loop in the opposite direction causes the output to decrease. The tuned

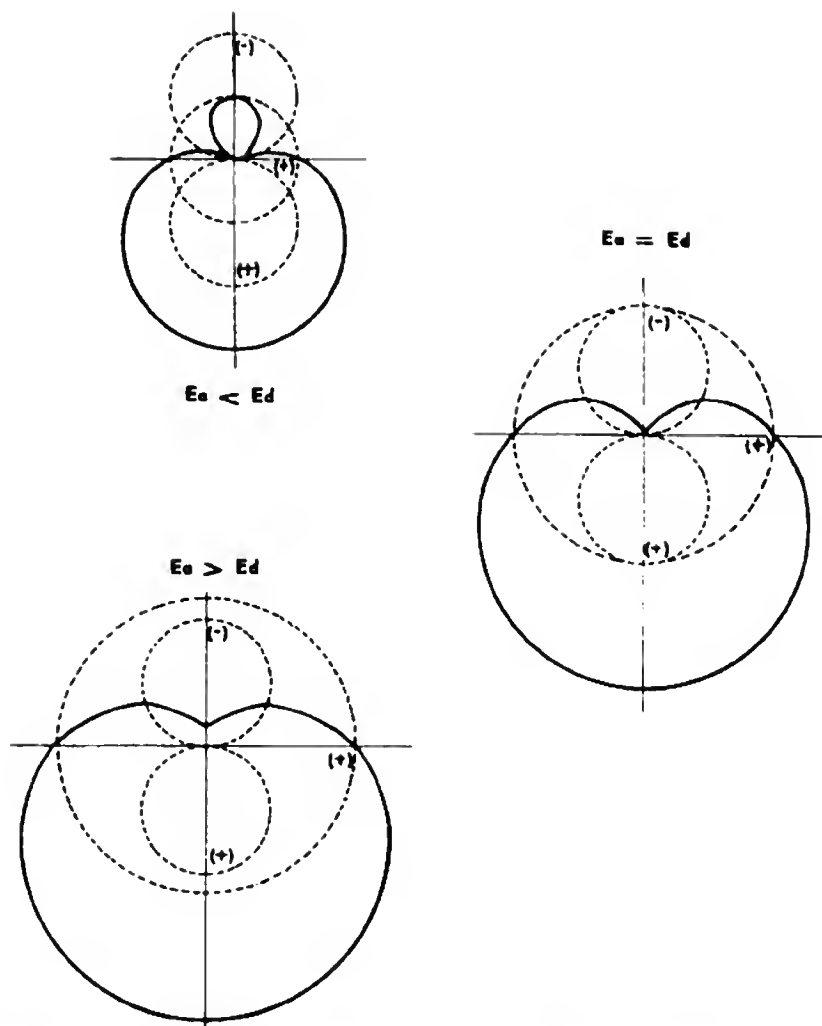


Figure 9-9.—Patterns obtained by combining sense voltage  $E_s$  and differential voltage  $E_d$ .

circuits are oriented so that by rotating the loop in a prescribed manner the operator can determine which is the correct null. If the signal strength increases with clockwise rotation of the loop, the operator knows that the observed bearing is correct. If the signal strength decreases with clockwise rotation of the loop, the operator knows that the correct bearing is the reciprocal of the observed bearing.

Figure 9-9 shows patterns that may be obtained by coupling different amounts of sense voltage into the loop

and then rotating the loop through  $360^\circ$ . The first pattern is obtained when the sense voltage  $Ea$  is less than the differential voltage  $Ed$ . The second pattern is obtained when the two voltages are equal. This pattern is a true CARDIOID. The third pattern occurs when the sense voltage is greater than the differential voltage.

In practice the sense antenna is designed to obtain a good balance voltage over the frequency range of the direction finder. The ideal pattern is a true cardioid. However, this ideal pattern is not necessary, since only a definite indication of either an increase or a decrease of loop output is needed to make the loop unilateral.

### BELLINI-TOSI ANTENNA SYSTEM

The Bellini-Tosi antenna system does not require that the antenna of the direction finder be rotated to obtain a bearing. This system uses two fixed loop antennas at right angles to one another, the loops being coupled to the receiver by a GONIOMETER. A goniometer consists of two field coils or stators, whose axes are at right angles to each other, and a rotating search coil or rotor which can be rotated through  $360^\circ$ . Each of the two fixed loops is connected to its corresponding goniometer stator. A simplified diagram of a Bellini-Tosi antenna and goniometer is shown in figure 9-10.

The advantage of the Bellini-Tosi system is that the antenna can be located at a remote position and coupled to the receiver over a relatively long length of transmission line. If a transmitted wave cuts loop 1 in figure 9-10 in such a direction as to induce maximum differential voltage in that loop, no flux links loop 2. Hence, no differential voltage is induced in loop 2. The differential voltages appear across their respective coils in the goniometer. These coils have the same angular displacement as the two loops. Therefore, the differential voltage from loop 1 appears across coil 1. There is no voltage across

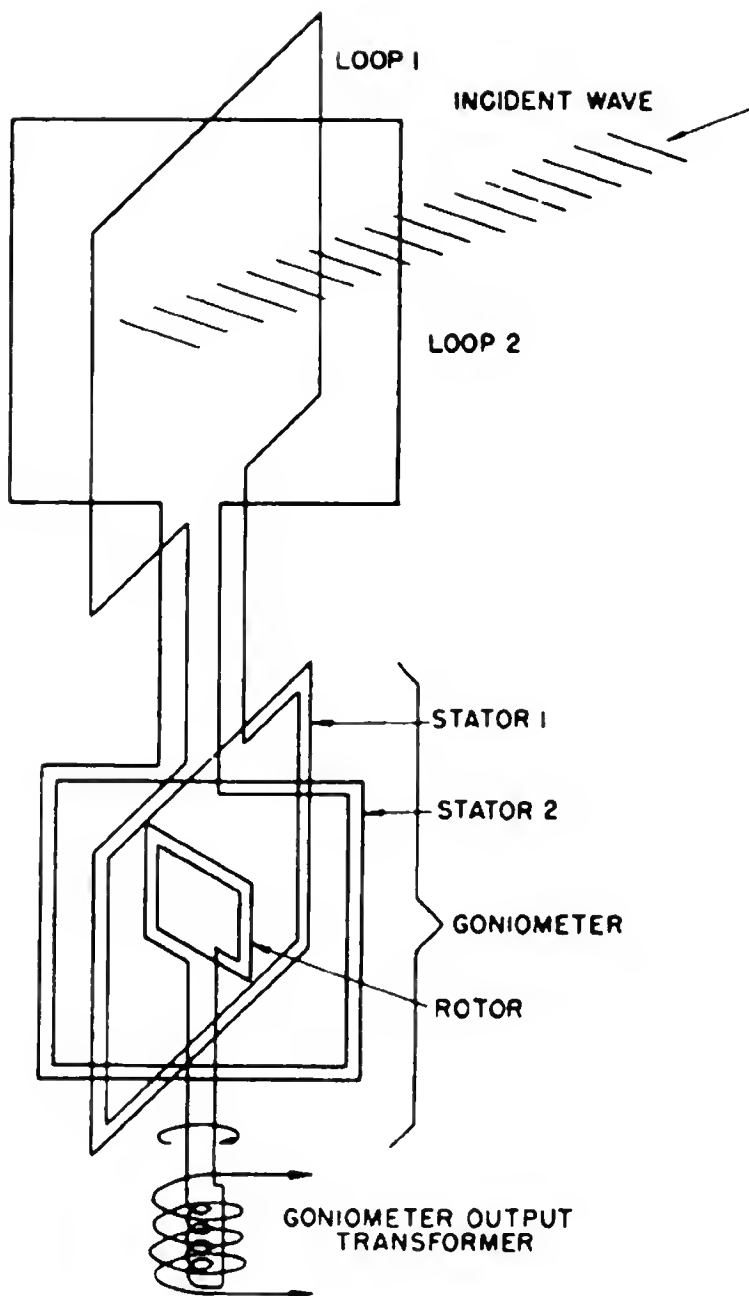


Figure 9-10.—Bellini-Tosi antenna system.

coil 2, since there is no voltage induced in loop 2. In order to obtain a null, the pick-up coil must be turned until it is at right angles to coil 1.

Now suppose that a signal links loop 2 and produces

maximum differential voltage in loop 2. This voltage appears across coil 2. The pick-up coil must be turned until it is at right angles to coil 2 to obtain a null. The shaft connected to the pick-up coil carries a pointer to indicate the bearing. At some intermediate bearing a differential voltage is developed in each loop. The amount of voltage depends on the bearing of the received signal. The two differential voltages appear across their respective coils. The pick-up coil must be positioned so that no voltage is induced in it. Sense and balance voltages may be obtained in the Bellini-Tosi antenna in the same manner as in the case of the rotating loop antenna.

### MODEL DBM-1 DIRECTION FINDER

The model DBM-1 direction finder shown in figure 9-11 is used principally in radar countermeasures in-

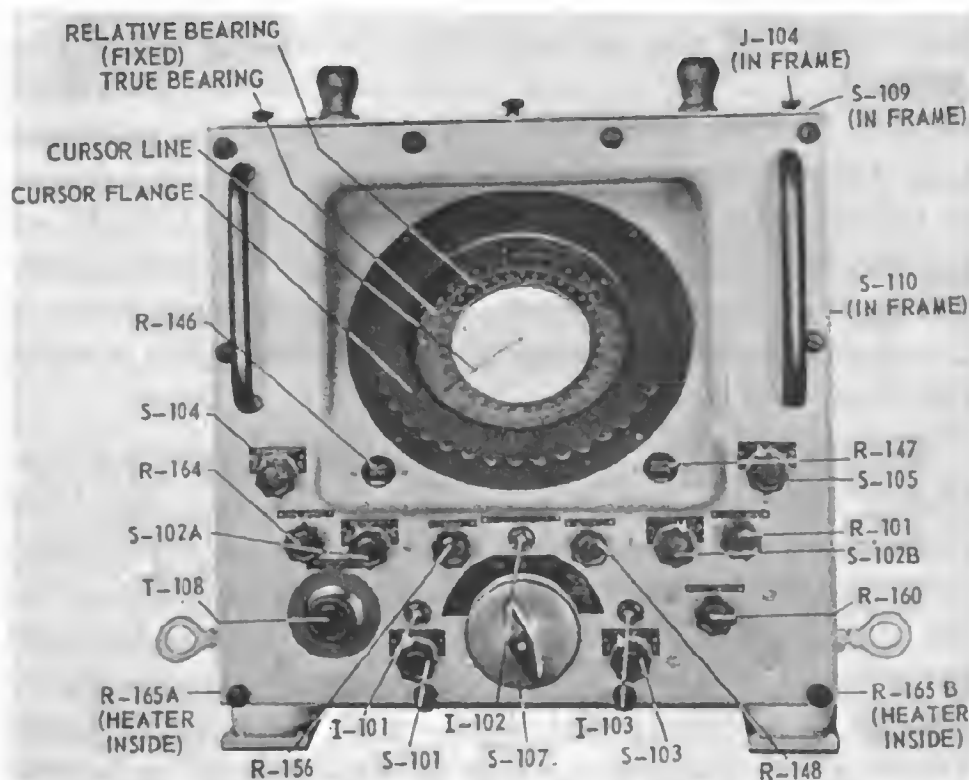


Figure 9-11.—DBM-1 direction finder, indicator unit.

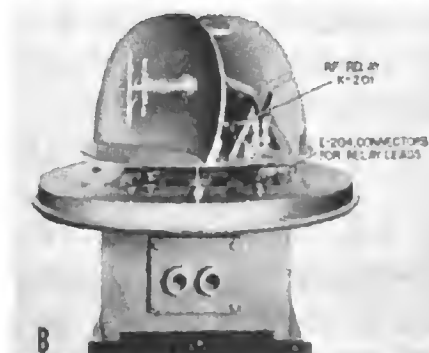
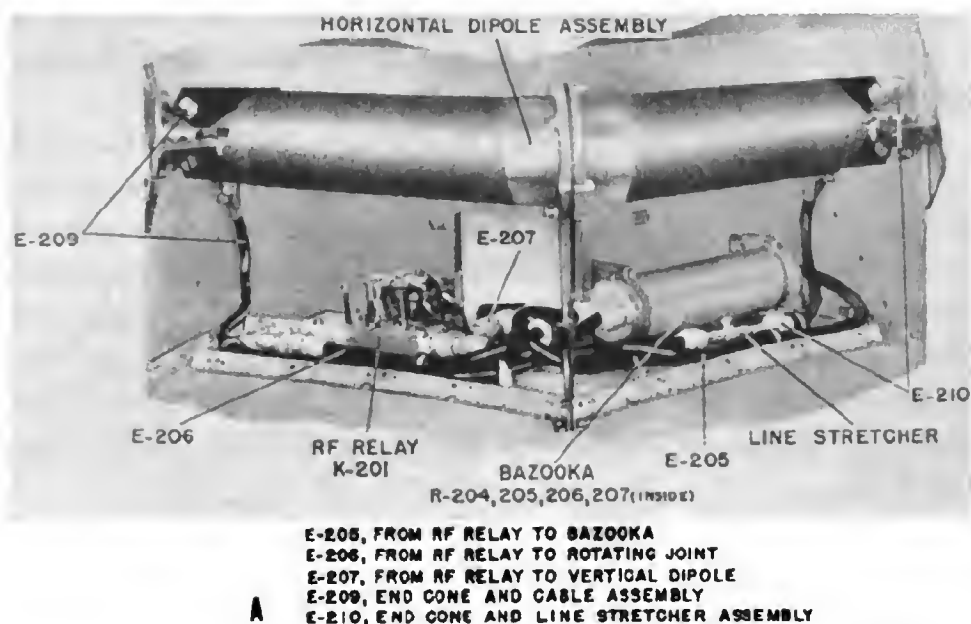
stallations. With this equipment it is possible to analyze radar and radio transmissions. It is used to determine the type of modulation and to estimate pulse width, repetition rate, and speed of rotation of the radar antenna. The DBM-1 consists of two antennas and an indicator unit used with two radar countermeasures receivers, such as the RDO and the SPR-2. The indicator unit presents the received signals on a cathode-ray tube.

### **Antennas**

The type CBM-66139 antenna (figure 9-12,A) covers a frequency range from 90 megacycles to 1,200 megacycles. The type CBM-66140 antenna (figure 9-12,B) covers a frequency range from 1,000 megacycles to 5,000 megacycles. Each antenna consists of two sections—a vertically-polarized antenna and a horizontally-polarized antenna. A relay in each antenna is controlled from the front panel of the indicator unit. It selects either the vertically-polarized section or the horizontally-polarized section. The choice of antennas depends on the polarization of the received signal. By switching from the vertical to the horizontal antenna while noting the strength of the received signal, the polarization may be determined. A Variac on the front panel of the indicator unit controls the speed at which the antennas rotate. The speed is variable from 0 to 150 r.p.m.

Several of the difficulties encountered with low-frequency direction finders are eliminated at the ultra-high frequencies. Because there are no sky waves, night effect is nonexistent. The reflector behind the antenna gives the antenna a unilateral pattern. This eliminates the need for a sense antenna. Locating the antenna a few wavelengths away from closed loops results in negligible quadrature effect. Because no loop is used, balance voltage is unnecessary.





**Figure 9-12.—Antennas installed with the DBM-1. A, Type CBM-66139 antenna, B, type CBM-66140 antenna.**

The two antennas used with the DBM-1 have identical antenna drive units. The antenna drive assemblies are housed in weatherproof metal enclosures and a radome protects the antenna itself.

The transmission line is connected to the ends of the low frequency horizontal dipole assembly instead of at the center. Two short sections of coaxial line connect the ends to a bazooka, a transforming device which changes the balanced output of the antenna with respect to ground to an unbalanced output. The bazooka does not

match the impedances of the two lines, but acts as a 1-to-1 transformer with a balanced primary and an unbalanced secondary.

One section of the coaxial line which connects the end of the dipole to the bazooka is shorter than the other. To keep the circuit symmetrical, a line stretcher is placed in the short cable. The output of the bazooka is connected to a rotating coaxial joint in the base of the antenna and then through a coaxial transmission line to the receiver. A pair of slip rings is used to connect the antenna relay K201 to the leads supplying power to it from the indicator unit.

At certain frequencies below 300 Mc the vertical antenna becomes more sensitive than the horizontal section—that is, a signal may be received with a greater intensity when using the vertical antenna although the signal is actually horizontally polarized. This condition is most pronounced when there are reflecting objects in the vicinity of the antenna. To keep the response of both antenna sections equal, a small filter or equalizer is placed in series with the vertical section.

The high frequency antenna CBM-66140 (figure 9-12,B) is similar to some types of radar antennas. Each of the two sections of the antenna consist of a dipole, a reflector element, and a parabolic reflector. The two sections are mounted back-to-back. The reflector element in front of the dipole causes the signal induced in the dipole to be principally that signal reflected from the parabolic reflector. This reduces the amount of signal picked up by the dipole from direct signals. This is equivalent to increasing the directivity of the antenna.

### Servo System

Figure 9-13 is a schematic diagram of a servo system used in the DBM-1 for true bearing operation. The true bearing scale is located around the screen of the cathode-

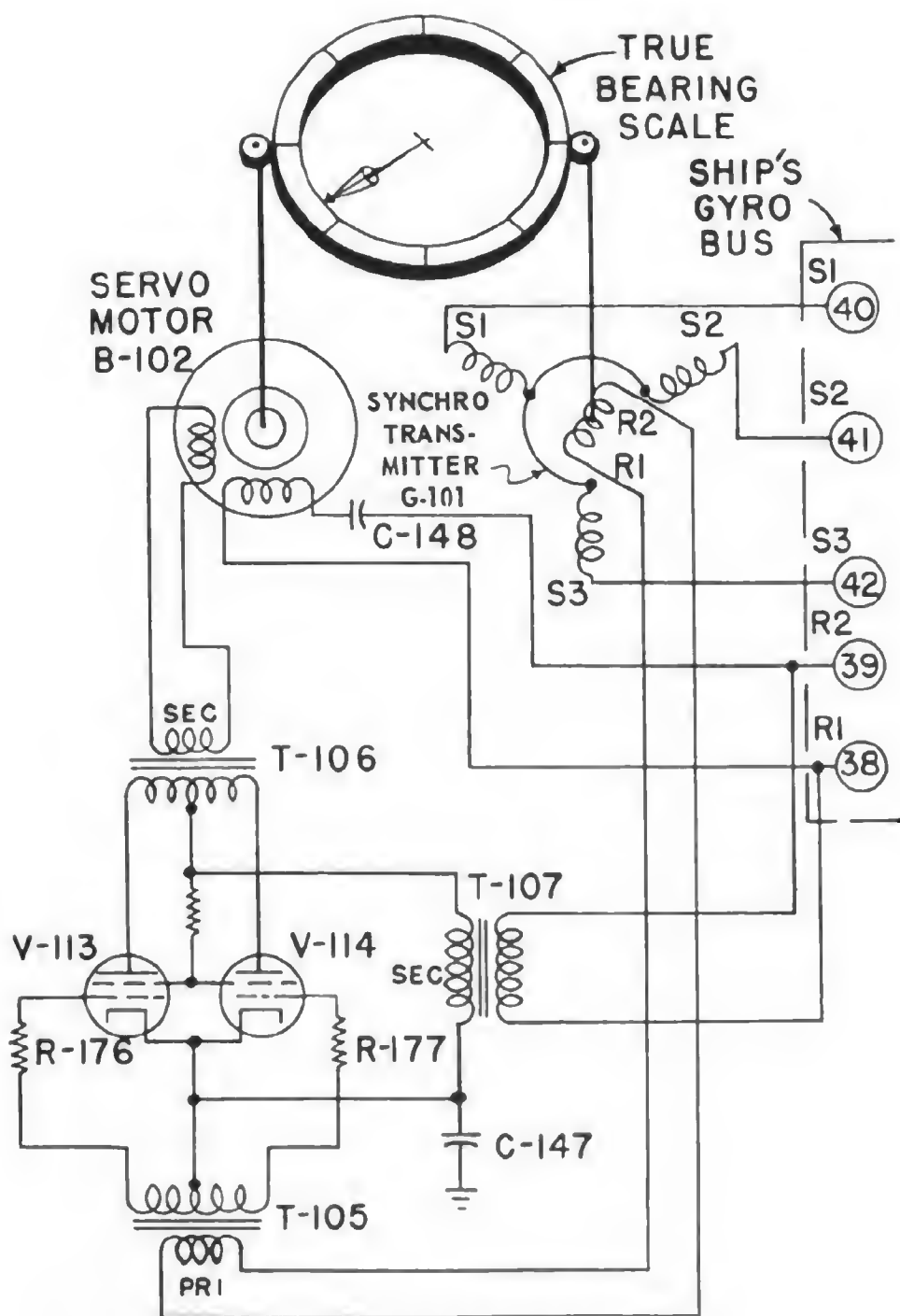


Figure 9-13.—Schematic diagram of the servo system for true bearing operation.

ray tube of the indicator unit. The stator windings of the synchro transmitter G101 are connected to the ship's gyro bus. As the ship changes course the servo motor turns the true-bearing scale synchronously with the change in course. The transmitter is not used here as a transmitter. Instead it functions as a control transformer. When the ship changes course, an error voltage is induced in the rotor winding of G101.

Since the transmitter is connected as a control transformer (no rotor excitation), no torque is developed and the rotor cannot turn. The error voltage induced in the rotor appears across transformer T105. Depending on the phase of the error voltage, the control grid of one of the amplifier tubes, either V113 or V114, is positive and the other is negative.

The plate and screen voltages for these tubes are obtained from the same source that supplies voltage to the synchro transmitter at the gyro compass and to one field of the servo motor. If the top of transformer T107 is positive with respect to ground, the plates and the screen grids of both tubes are positive. When the top of T107 is negative with respect to ground, the plates and the screen grids of both tubes are negative. The direction in which the rotor of the synchro transmitter at the gyro compass turns determines the polarity of the error voltage with respect to the voltage across the primary of T105. It is the polarity of this error voltage that determines in which direction the servo motor turns.

Assume that the error voltage causes a voltage to exist across the secondary of T105 so that the grid of V113 is positive and the grid of V114 is negative. When the a-c voltage on the plates and the screen grids of these tubes is positive, tube V113 conducts. Tube V114 cannot conduct because its grid is negative. The current through V113 flows through one half of the primary winding of

T106. A voltage is induced in the secondary winding, causing the servo motor to rotate.

Now assume that the error voltage is of the opposite polarity. Tube V114 conducts and current flows in the opposite direction in the other half of the primary winding of T105. In this case the servo motor rotates in the opposite direction.

As the servo motor rotates, it turns the true bearing scale. Since the rotor of G101 is geared to the scale, it turns with the scale. The error voltage induced in the rotor is reduced until there is no error voltage developed across the rotor of G101. When the error voltage is reduced to zero, the servo motor stops.

The servo motor is a two-phase motor. The excitation for one winding is obtained from the amplifier and is either in phase or  $180^\circ$  out of phase with respect to the primary voltage T107. The excitation for the other winding is obtained from the same source, but capacitor C148 shifts its phase  $90^\circ$  with respect to the voltage across the primary of T107.

When the antenna selector switch is placed in the relative bearing position, the stator leads of the synchro transmitter are disconnected from the gyrocompass bus and are connected to the primary of transformer T107. With this connection, 78 volts alternating current is applied to the stator of G101. The fixed a-c supply induces a signal in the rotor causing the servo system to drive the bearing dial to zero. Having reached zero, the bearing dial remains at this position and is independent of OSC.

### Indicator Unit

The indicator unit of the DBM-1 contains a series of video amplifiers which amplify the output of the associated receiver and display the received signals on a cathode-ray tube. The input to the video amplifiers from the receiver must be negative.

A schematic diagram of the indicator unit is shown in figure 9-14. Relay K103 with its contacts as shown in the diagram connects the output of the high frequency receiver to the indicator. The action of K103 depends on the position of the antenna selector switch. Potentiometer R101 is used to adjust the amount of the video signal placed on the grid of the first video amplifier. The following stages amplify the signal which is coupled through capacitor C113 to the grid of the output stage V104. Potentiometer R160 is used to adjust the amount of negative bias placed on the grid of the output stage.

The signal appearing in the plate circuit of V104 is composed of negative pulses which are capacitively coupled to the rotors of the scanning capacitor C142. Part of the output of V104 is coupled also to the grid of the beam modulator tube V108. This tube supplies a positive output to the grid of the cathode-ray tube when a signal is being received. It keeps the CRT blanked when no signal is received. The intensity control R148 is adjusted so that, when no signal is being received, the cathode-ray tube is cut off. However, when a signal is received, the positive voltage from V108 is sufficient to raise the CRT above cutoff and a signal appears on the screen.

### Scanning Capacitor

The rotor of the scanning capacitor is rotated in step with the antenna by means of B101. The scanning capacitor applies the output of the video amplifiers to the deflection plates of the cathode-ray tube in such a manner that the pattern on the cathode-ray screen is pointing on the same bearing as the antenna. A simplified diagram of the operation of the scanning capacitor is shown in figure 9-15.

The amount of signal coupled to the individual deflection plates depends on the position of the rotor with

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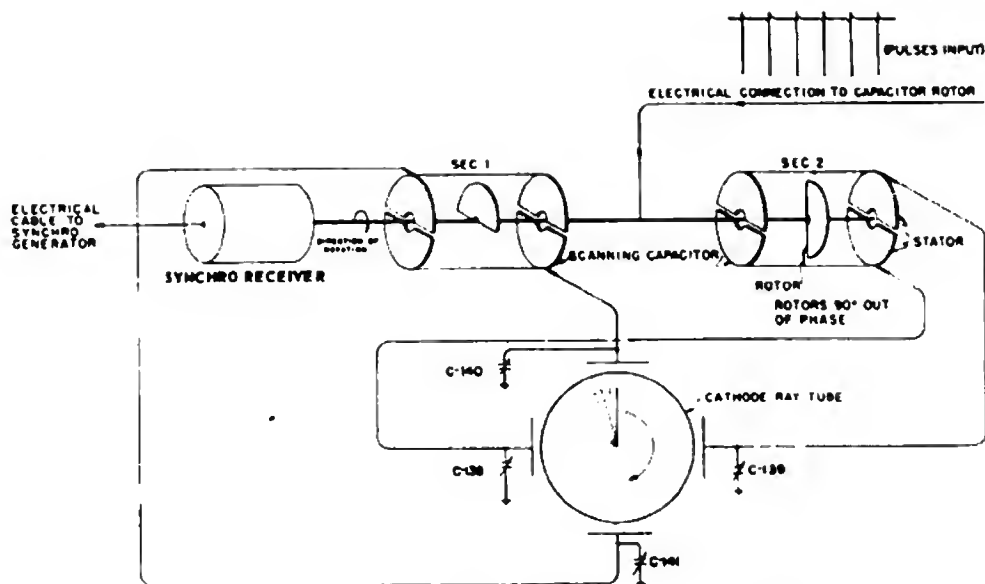


Figure 9-15.—Simplified diagram showing the operation of the scanning capacitor.

respect to the stator. The position of the rotor depends on the position of the antenna. The signal placed on the deflection plates is a negative voltage. This voltage repels the electron beam instead of attracting it.

The electron beam is deflected toward the top of the tube when the rotor is in the position shown in the diagram. The signal is coupled to the lower vertical deflection plate because of the capacity between the rotor and the top of section 1. No signal is coupled to the upper vertical deflection plate. Section 2 of the capacitor couples an equal amount of signal to both horizontal deflection plates. The signal placed on the horizontal deflection plates has no effect on the electron beam because the voltages are equal and of the same polarity. When a signal is coupled to both a horizontal deflection plate and a vertical deflection plate, the direction in which the electron beam is deflected depends on the vector sum of the two voltages. Trimmer capacitors are used to balance the capacity of the different stators of the scanning capacitor.

Refer again to figure 9-14. When the antenna being

used is switched from the vertically polarized section to the horizontally polarized section or vice versa, the signal still appears on the same bearing. However, if it were not for relays K101 and K102, the signal would appear on the reciprocal bearing because the two antenna sections are displaced  $180^\circ$ . These relays interchange the stator plates of the capacitor so that the signal appears on the same bearing when the polarization of the antenna is changed. The action of these relays depends on the position of the horizontal-vertical switches.

### **D-c Restorers**

The d-c restorers, V106 and V107, prevent the positive half-cycle of a signal from causing the trace on the cathode-ray tube to pass through the center of the screen. These stages are not necessary for the radar pulses because radar pulses are all negative. However, when radio-telephone or radiotelegraph signals are received, the signal pattern could not start from the center of the screen, if it were not for the d-c restorers. The telephone and telegraph signals consist of both positive and negative voltages.

The d-c restorers maintain a fixed negative d-c potential. A positive signal causes the d-c restorers to conduct and prevents positive signals from affecting the deflection of the electron beam. Also, by changing the bias on the d-c restorers, the potentials appearing on the deflection plates can be adjusted so that the electron beam is centered on the screen.

### **DBM-1 Indicator Patterns**

A few of the patterns that may be obtained with the DBM-1 are shown in figure 9-16, A through E. The pulse repetition rate can be estimated by the spacing between the traces of the pattern. This depends on the pulse repe-

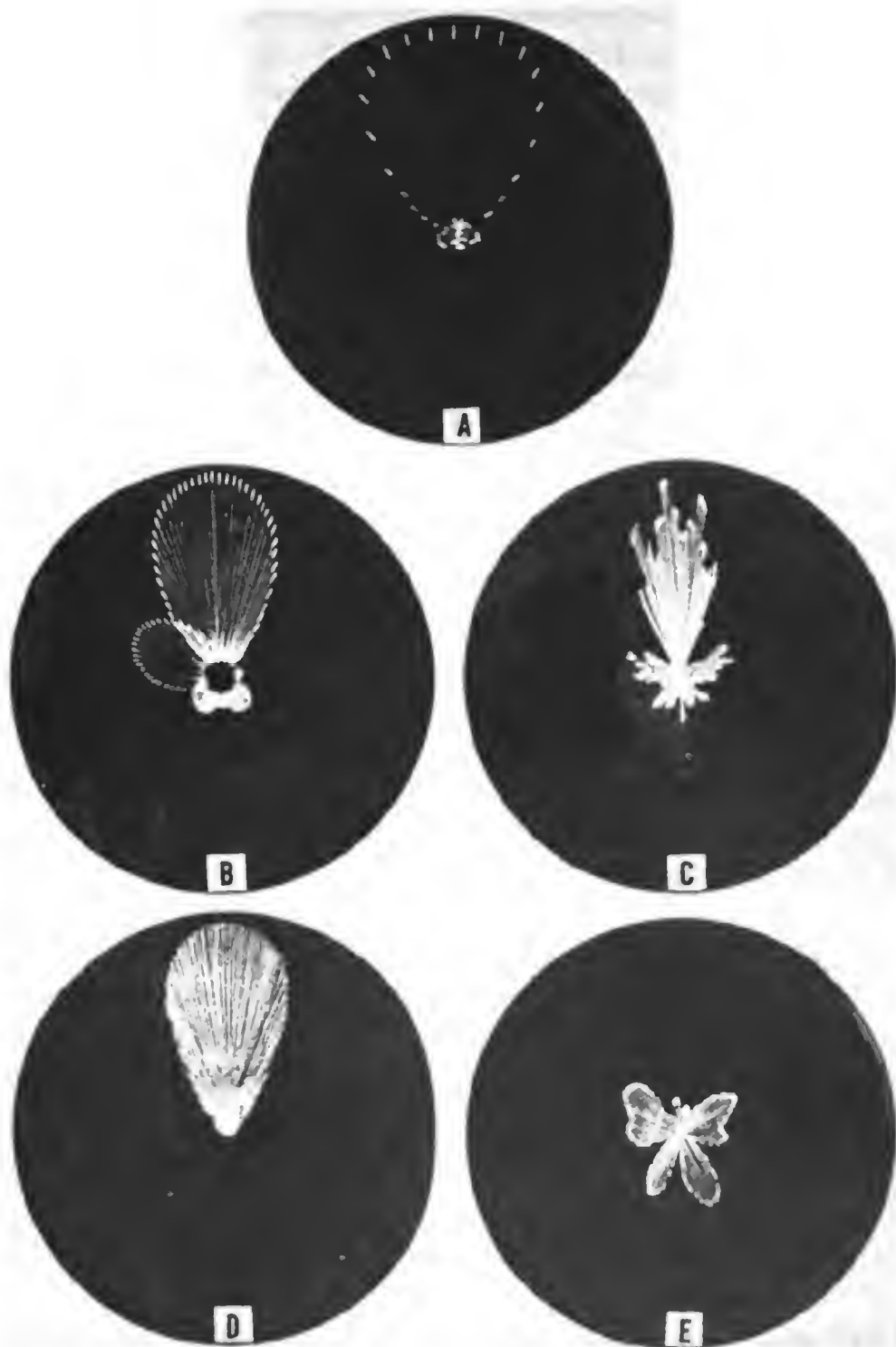


Figure 9-16.—Indicator patterns. A, Low PRF search radar, B, reception of two signals, C, lobe switching fire control radar, D, radiotelephone signal, E, polarization of the DBM-1 antenna different than that of the received signal.

tition rate of the transmitting radar and the speed of rotation of the DBM-1 antenna. The pulse width of the intercepted signal can be estimated by the length of the brightened ends of the traces.

The ratio of the length of the bright tip to the total trace length expressed in percent is approximately equal to the pulse width in microseconds. If the bright tip is about 5 percent of the total length of the trace, the pulse width is approximately 5 microseconds. Communications signals can be identified because they do not produce any bright tips on the trace and in general their pattern has a fuzzy appearance.

## QUIZ

1. Name two essential components of a radio direction finder.
2. In what frequency range do most radio direction finders operate?
3. Why are ground waves generally used for obtaining bearings with a radio direction finder?
4. Name the two components of a radio wave.
5. A radio wave has a horizontal magnetic field. How is the radio wave polarized?
6. Radio direction finding makes use of which field component of the radio wave?
7. How is a radio direction finder loop antenna made insensitive to the electric field component of the transmitted wave?
8. What is the purpose of the insulated segment in the direction finder loop antenna shield?
9. What is the relative diameter of an RDF loop antenna compared to the wavelength of the operating signal?
10. What is the position of maximum induced voltage in an RDF loop antenna with respect to the direction of travel of a vertically-polarized radio wave?
11. What is the phase relation between maximum induced voltage in the RDF loop antenna and the magnetic field component of the radio wave?

12. Is the RDF loop antenna bidirectional or is it omnidirectional?
13. What causes the absence of a null position in an unbalanced and unshielded loop antenna?
14. What is quadrature effect in a loop antenna?
15. How is quadrature effect reduced in a loop antenna?
16. What is the phase relation between the reradiated field from the compensating loop and the reradiated field from nearby objects?
17. What is meant by polarization error, or night effect?
18. Introducing the sense voltage into a loop antenna changes the bilateral pattern. What is the new pattern called?
19. What is the phase relation between the differential loop voltage and the voltage induced in the vertical antenna of the RDF?
20. What is the phase relation between the primary and secondary voltages in the transformer that couples the loop antenna circuit to the vertical antenna circuit in the RDF?
21. What is the phase relation between the differential loop voltage and the sense voltage in the RDF?
22. What feature of the coupling transformer eliminates the quadrature relation between the differential loop voltage and the sense voltage in the RDF?
23. What is the purpose of the model DBM-1 direction finder?
24. Name three advantages of u-h-f direction finders as compared to low frequency types.
25. What is the purpose of the bazooka in the DBM-1 equipment?
26. What is the function of the indicator units associated with the DBM-1 direction finder?
27. How is the bearing of the pattern on the cathode-ray screen related to the antenna bearing in the DBM-1?
28. What is the function of the d-c restorers in the DBM-1 indicator unit?
29. A DBM-1 indicator pattern displays a pattern of a low PRF search radar. How are the spaces between the traces of the pattern related to the pulse repetition frequency?



## LORAN TRANSMITTING EQUIPMENT

### PRINCIPLE OF LORAN

The loran system was designed to provide a means of obtaining navigational fixes by using low frequency radio signals. The word "loran" is a combination of the first letters of the words LONG RANGE Navigation. With loran, accurate fixes can be obtained at much greater distances from transmitting stations than is possible with conventional radio direction finding. During the day, over sea water, fixes are possible up to 700 nautical miles from the loran transmitting stations. At night, making use of sky waves, distances up to 1400 miles are possible. However, fixes using sky waves are not so accurate as those made with ground waves.

Loran fixes compare favorably in accuracy with celestial fixes. Loran has three advantages over celestial fixes. First, loran may be used as well in a heavy fog as in clear weather. Second, loran readings can be made rapidly. Third, loran fixes can be made at any time of the day or night in the area covered by the stations observed.

The principle of loran is based on the difference in time required for pulsed radio signals to arrive from a pair of synchronized transmitters. Loran transmitters are installed on shore several hundred miles apart. The principle of loran is illustrated in figure 10-1, A. If sta-

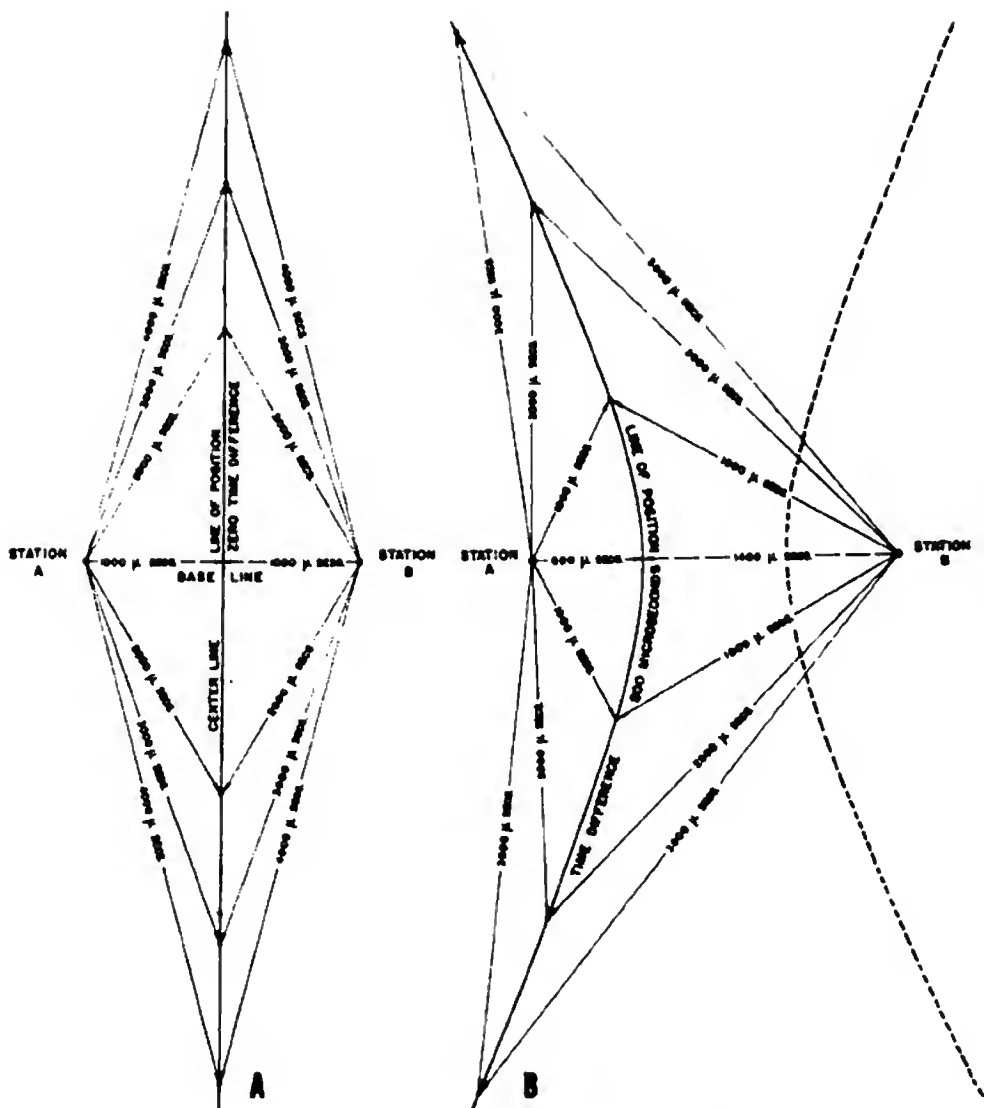


Figure 10-1.—Principle of loran simplified. A, Line of zero time difference, B, hyperbolic line of position.

tions A and B are pulsed simultaneously, the two pulses arrive at any point on the centerline at the same time.

Suppose that an observer is located closer to station A than to station B. Then the pulse from station A will arrive at his location before the pulse from station B.

A specific time difference will be noted at a number of points as shown in figure 9-1, B. These points lie on a

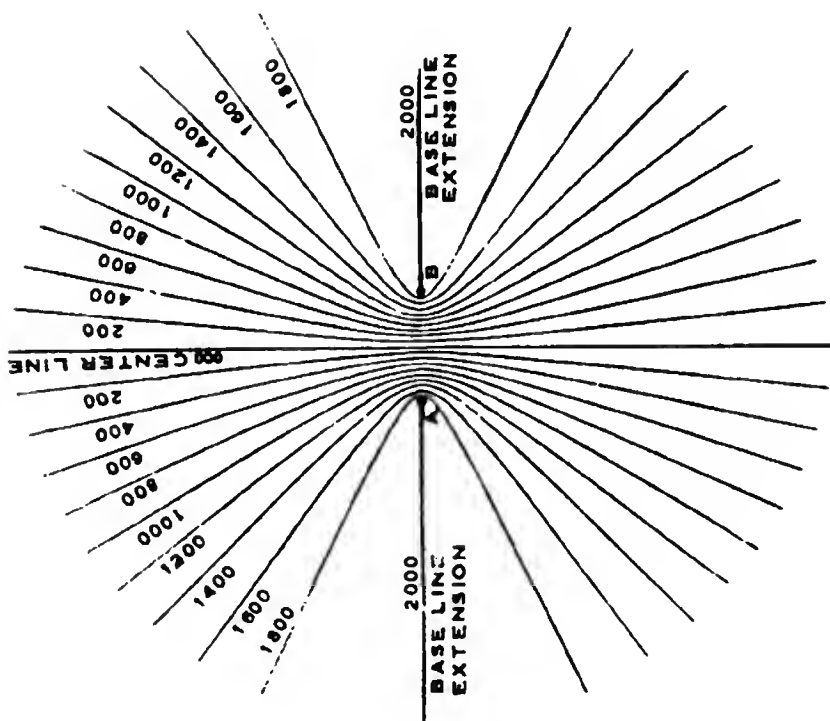


hyperbola. Connecting the points where the time difference is the same forms a line of constant time difference, or hyperbolic line of position. This is the left branch of the hyperbola shown in figure 10-1, B. Notice that it is concave toward *A*. Stations *A* and *B* are the foci of the hyperbola. A time measurement indicates that the observer is somewhere on a particular line of position but does not indicate his position on the line.

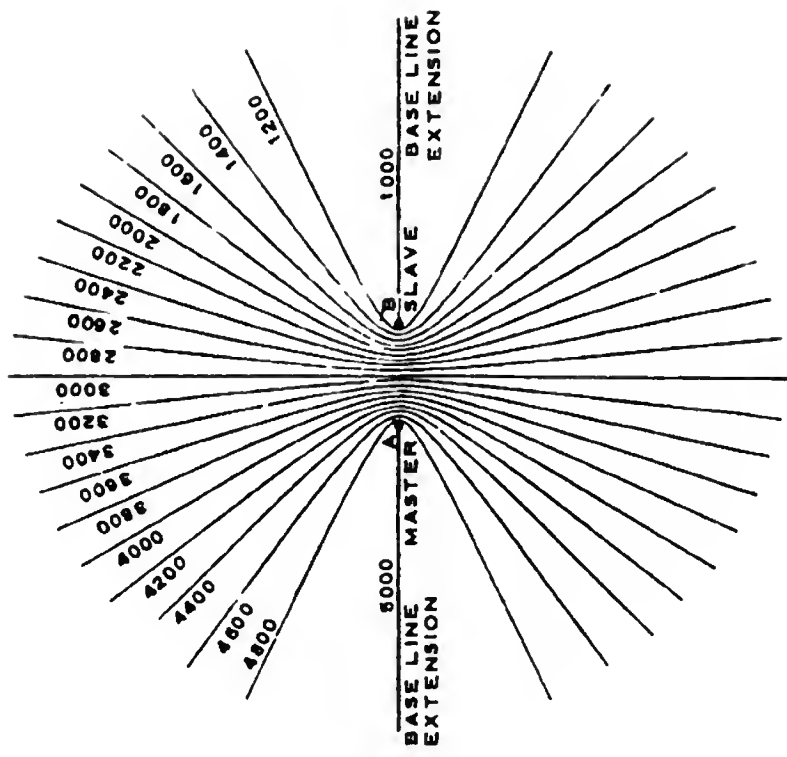
Assume now that the observer is on the side of the centerline toward *B*. Then the line of constant time difference is the right branch of the hyperbola appearing in figure 10-1, B. If the pulses from the transmitters are identical, the observer has no way of telling which pulse arrives first. In this case the observer cannot determine which branch of the hyperbola is the true line of position. The ambiguity is overcome and at the same time the time measurement made by the observer is simplified by delaying the pulsing of one of the transmitters.

From the foregoing explanation it follows that many lines of position may be obtained. By selecting several time differences for a given pair of stations the result is a family of hyperbolas like those shown in figure 10-2, A.

In actual practice, one station of the loran pair is designated the master station. It establishes the pulse repetition rate (PRR). The second, or slave station, receives the pulses of the master station and transmits its own pulses delayed in time but in synchronism with master pulses. The time delay between the transmission of a pulse from the master station and the arrival of this pulse at the slave station depends chiefly upon the distance between the stations. After the pulse arrives at the slave station there is a time delay of one-half the pulse-repetition period. This is introduced inherently by the two-trace method of cathode-ray-tube presentation used with a loran indicator.



**A**



**B**

Figure 10-2.—Lines of position. A, No time delay, B, 3,000-microsecond delay.

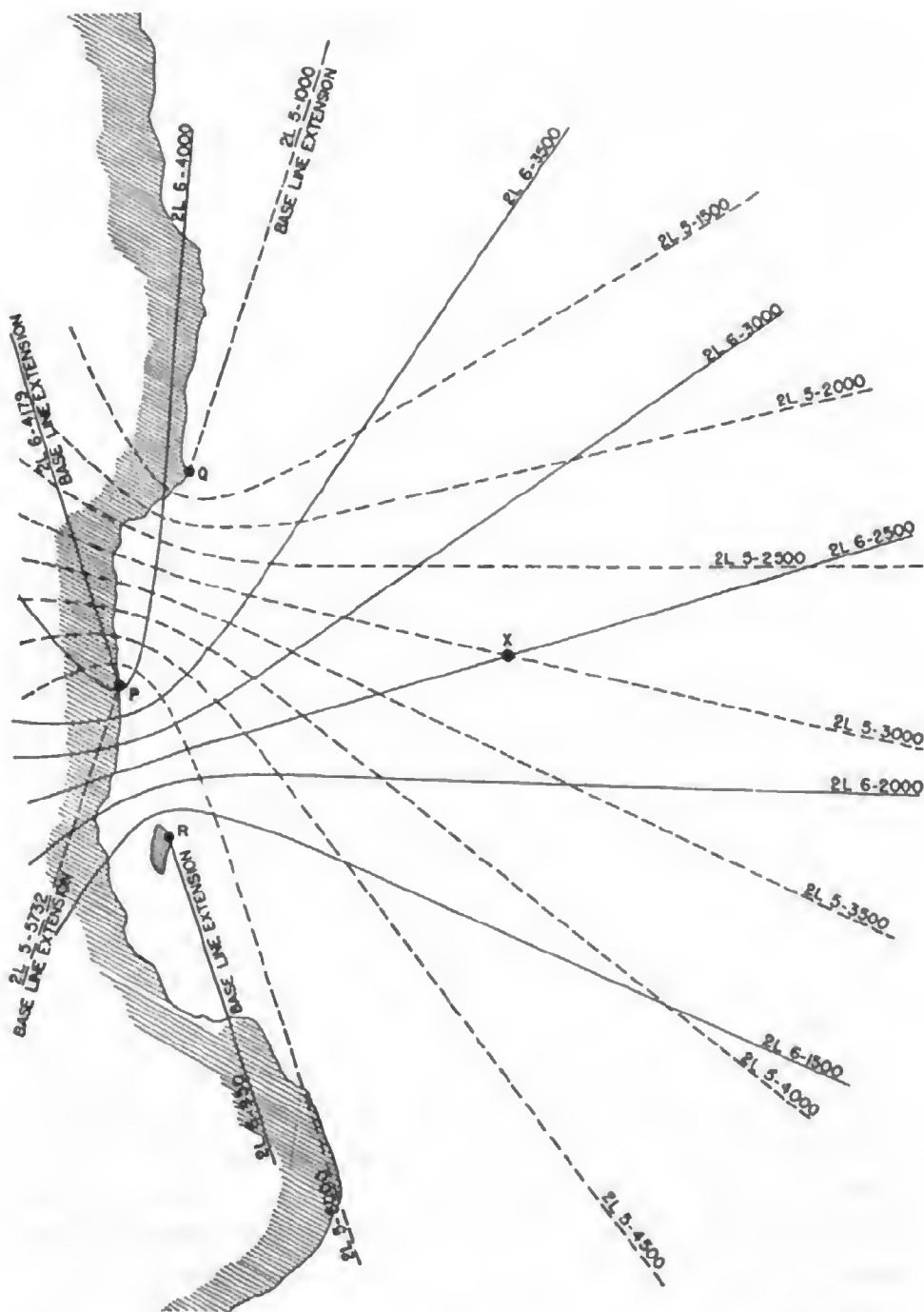


Figure 10-3.—Obtaining a fix with one master and two slave stations.

In addition to these two delays another delay called the CODING DELAY is added. The sum of the three delays

is called the **ABSOLUTE DELAY**. The absolute delay is the time between the transmission of a pulse from the master station and the transmission of a pulse from the slave station. The absolute delay in figure 10-2, B, is 3000 microseconds.

The PRR is different for different pairs of stations to enable the operator to identify the pair to which the receiver is tuned. If the master station PRR changes, it is necessary to correct this condition at the master station in order to preserve the identity of the pair. If the two stations of a pair become asynchronous they are brought into synchronism again by making the necessary adjustment at the slave station. If the basic time delay between the master and slave transmission changes, the correction is made at the slave station. Time intervals differ for various pairs of stations in order to prevent interference from other pairs of loran stations operating on the same channel.

A loran fix is the point of intersection of two lines of position. Finding two lines of position requires two pairs of transmitting stations. One pair of stations acts as foci for one family of hyperbolas. The second pair of stations acts as the foci for another family of hyperbolas. A fix will be the intersection of two hyperbolas, one from each family.

Figure 10-3 shows how a fix is obtained by using only one master and two slave stations. This is accomplished by causing the master station to transmit two distinct sets of pulses. The double-pulsed master station transmits one set of pulses at the PRR of the pulses transmitted by the first slave station and the other set of pulses at the PRR of the pulses from the second slave station.

Lines of position are identified by a letter and several numbers. The letter represents the basic PRR—special (S), low (L), or high (H). (The special basic PRR is

not in current operational use.) The first number is the channel or carrier frequency. The second number denotes the specific PRR. The last number is the time difference in microseconds. For example, 2L 6-2500 indicates channel 2 which is 1850 kc, a low basic PRR of 25 cycles per second, a specific PRR of 6 corresponding to  $25 \frac{6}{16}$  cycles per second, and a time difference of 2500 microseconds.

## LORAN CHANNELS

There are four loran channels, numbered 1 through 4, corresponding to carrier frequencies of 1950, 1850, 1900, and 1750 kc, respectively. At the present time only three channels are in use. In order to accommodate all loran stations on just a few channels, different pairs of stations use different pulse recurrence rates.

The basic pulse repetition rates are 20, 25,  $33\frac{1}{3}$  pulses per second. The basic PRR of 20 cycles per second corresponds to the special basic PRR and is not in use. The basic pulse recurrence rates are subdivided into specific pulse recurrence rates. The specific low PRR is from 0 through 7 corresponding to 25 through  $25\frac{7}{16}$  pulses per second in steps of  $\frac{1}{16}$  of a pulse per second. The specific high PRR is from 0 through 7 corresponding to  $33\frac{1}{3}$  through  $34\frac{1}{9}$  in steps of  $\frac{1}{9}$  of a pulse per second.

Loran stations operate in a portion of the radio spectrum which is fairly crowded. The frequency band required for loran stations is reduced by operating several pairs of stations on the same carrier frequency. As previously stated, each pair of stations transmits at a different PRR. Signals from all loran stations on the same channel appear on the indicator screen, providing the instrument is within range of the stations, but these signals drift across the screen at varying speeds. The operator can select a pair of stations by means of switches which cause the selected pulses to become sta-

tionary on the screen. The signals from other pairs continue to drift across the screen and can be ignored.

The general position of a ship is usually known before a loran fix is made. The person using the loran indicator can consult the loran charts for that particular area and note stations which are likely to be observed. From the symbols on the lines of position the channel, the basic

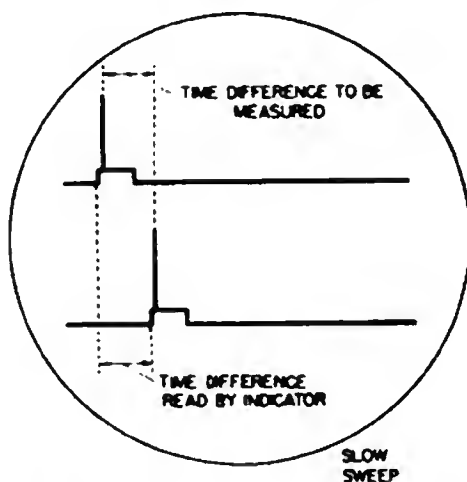


Figure 10-4.—Time difference measured on a loran indicator.

PRR, and the specific PRR can be determined. On the loran indicator the operator first selects the channel. Then by using the basic and specific PRR switches, a pair of pulses is made to appear stationary on the indicator cathode-ray tube screen. The time difference is then measured.

The indication appears on the loran indicator scope as two sweeps, one above the other. The pulse from the slave station is delayed about half the pulse repetition rate. The indication on the loran indicator scope is shown in figure 10-4. The pulse appearing on the top sweep is from the master station and the one on the bottom sweep is from the slave station. The actual time difference including the delay is the time it takes the sweep to travel from the master pulse across the screen retrace

to start the bottom sweep, and travel to the pulse from the slave station. However, the time measured is only the horizontal distance between the leading edges of the two pulses. Neglecting the rest of the time the sweep is in operation compensates for the slave pulse delay time.

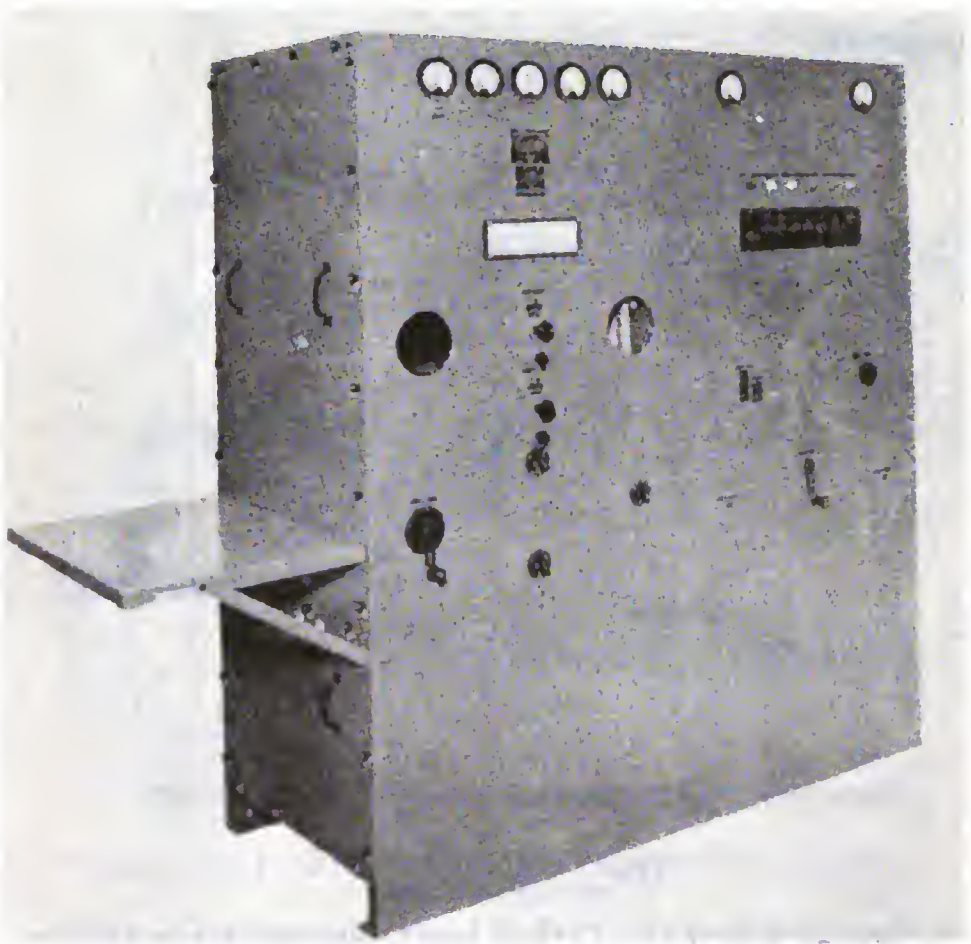


Figure 10-5.—TDP-1 loran transmitter.

## LORAN CHARTS

Loran charts for use aboard ships and aircraft are published by the Hydrographic Office. These charts are standard Mercator charts with lines of position printed on them. The lines are mathematically computed and are

plotted for 20-microsecond intervals. The lines of position for different pairs of stations are printed in different colors.

## LORAN TRANSMITTING EQUIPMENT

For a double-pulsed station the minimum equipment required is one transmitter, two timers, and a switching equipment.

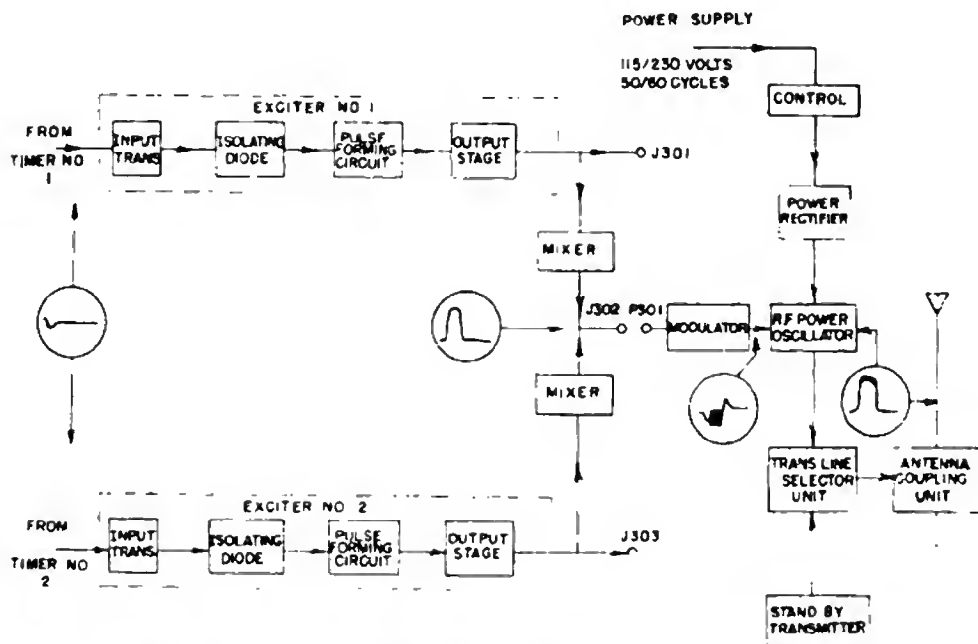


Figure 10-6.—Block diagram of the TDP-1 Loran transmitter.

### TDP-1 Transmitter

A photograph of the TDP-1 Loran transmitter is shown in figure 10-5. The frequency range of this transmitter is from 1700 to 2000 kc. When double-pulsed, it has a peak power output of 85 kilowatts. The duration of an output pulse is approximately 80 microseconds. Figure 10-6 shows a block diagram of the TDP-1. The output pulses from the timer are fed through the switching equipment to the transmitter. In many respects the TDP-1 is similar to a radar transmitter.



The TDP-1 transmitter contains two identical exciter units which are necessary, if the transmitter is double-pulsed. The output of the timer consists of both positive

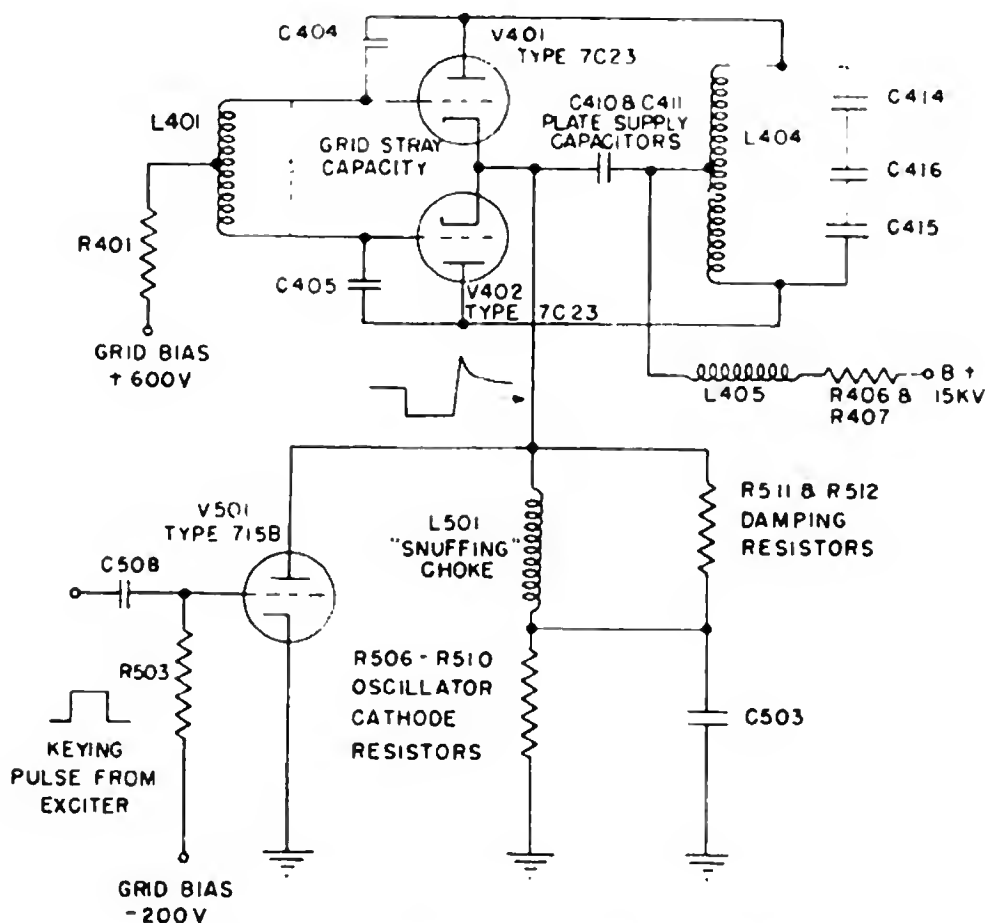


Figure 10-7.—Simplified schematic diagram of the modulator and the oscillator.

and negative pulses. An isolating diode allows only the positive pulses to reach the pulse forming circuit. The shape and duration of the pulses produced by the pulse forming circuit are determined by this circuit alone. The output of the pulse forming circuit is a series of positive pulses which cause the modulator to key the transmitter.

A simplified schematic diagram of the high power oscillator and modulator is shown in figure 10-7. When

no keying pulses are present, the modulator tube V501 is cut off by a large fixed bias on its grid. The oscillator is practically cut off by the cathode bias developed across resistors R506 and R510. The sum of the cathode voltage and grid bias supply voltage is an effective bias of  $-600$  volts on the grids of the oscillator tubes V401 and V402.

The modulator V501 conducts when a positive keying pulse is placed on its grid. The voltage on the cathodes of the oscillator tubes is reduced to about  $+500$  volts when the modulator conducts. The net grid bias is now positive on the grids of the oscillator tubes and oscillations build up rapidly. As soon as the grids of the oscillator tubes are driven positive, grid current flows and grid leak bias is developed across the grid resistor. This biases the tubes for class-C operation. The oscillator uses a push-pull tuned-plate tuned-grid circuit. Resistors in the plate return limit the current drawn from the power supply when the oscillator is pulsed. During the period that the oscillator is pulsed, plate power is supplied by capacitors C410 and C411. When the oscillator tubes stop conducting these capacitors charge from the power supply. The snuffing choke improves the keying of the oscillator by momentarily driving the cathodes of V401 and V402 about 2500 volts positive with respect to ground at the end of the keying pulse. This occurs as a result of the sudden change in current through the choke caused by the cutoff of V501. The output of the oscillator is fed through a coupling network to the antenna.

### UE-1 Timer

The same type of timer is used at both the master and the slave stations. A receiver in the UE-1 timer receives both the local and the remote signals. These signals are viewed on cathode-ray tubes to determine whether the master and slave stations are synchronized. Adjustments are made at the slave station.

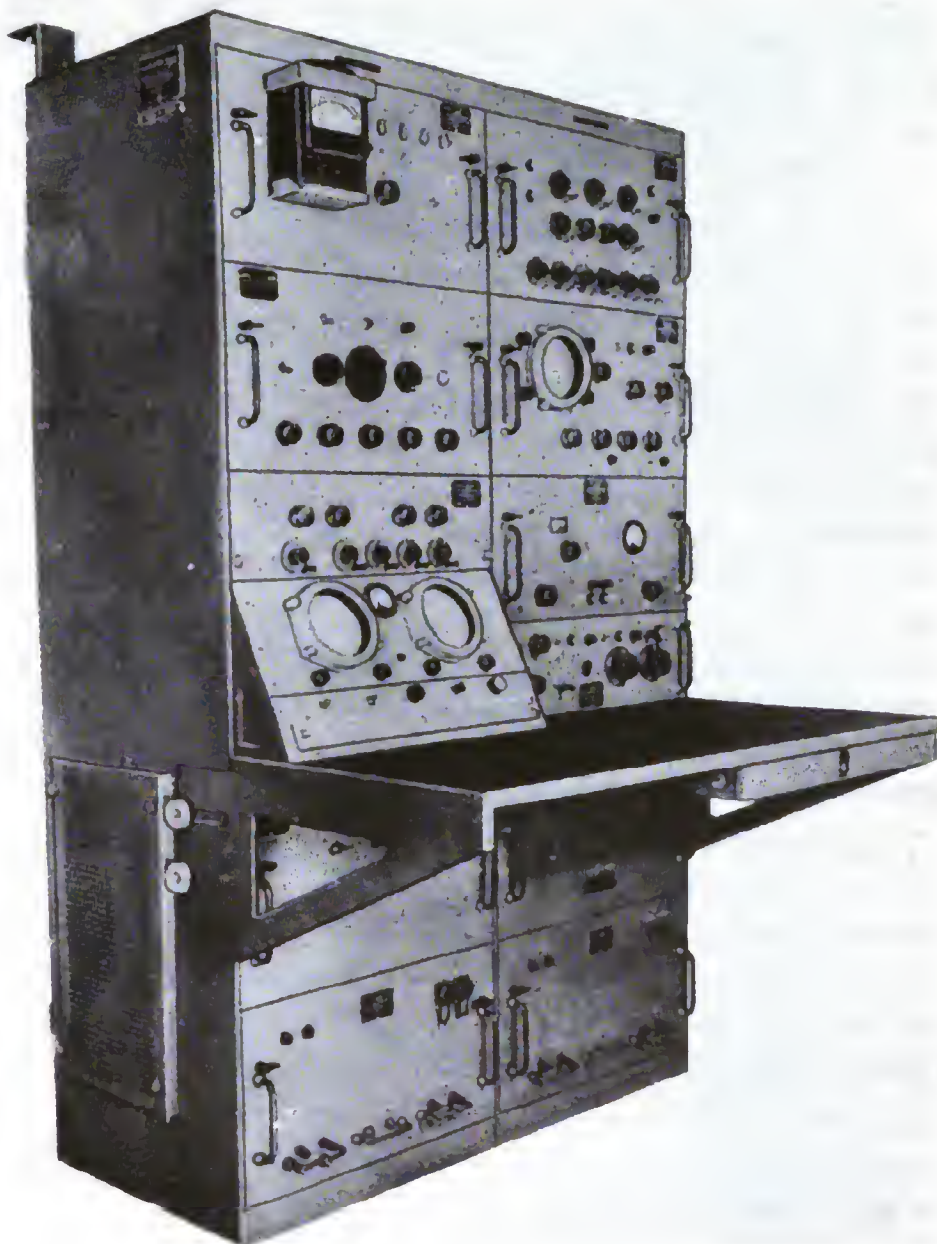


Figure 10-8.—UE-1 timer.

A very stable 100-kc crystal oscillator in the timer generates timing and marker pulses. The output of the crystal oscillator is fed through a series of counting circuits which divide the crystal frequency to obtain

pulses at the pulse repetition rate of the station. Figure 10-8 is a photograph of the UE-1 timer. The outputs of various counting circuits start the sweeps of the cathode-ray tubes, control multivibrators in the timer, and control the discriminator in the switching equipment.

The timer used at the slave station performs the following functions: (1) generates an extremely accurate timing signal; (2) receives the pulse signals from both the remote (master) station and the local (slave) station; (3) triggers the local transmitter at a predetermined time interval after the pulse from the master station is received; (4) generates the trigger pulse which actuates the slave transmitter; (5) provides an indication on an oscilloscope of the master pulse, the slave pulse, and markers from which the time relationship between the two pulses can be maintained; (6) provides a means for correcting the time interval between master and slave pulses and also for correcting the basic timing signal which controls that time interval.

To avoid confusion any adjustment of the time interval between the pulses from a master station and the corresponding pulses from a slave station is made at the slave station. This procedure is followed because the master station timer establishes the PRR and the slave station is synchronized with respect to the master station.

Because of the extreme accuracy required, the timer is composed of a large number of circuits. The master and the slave stations can be synchronized manually. Once they are synchronized, an automatic synchronization unit in the timer at the slave station assumes control of the synchronization. Nevertheless, operating personnel must be at the stations during periods of operation.

If the stations get out of synchronization, an automatic blinking circuit causes the pulses seen on the loran indicator screen to have a characteristic movement. This

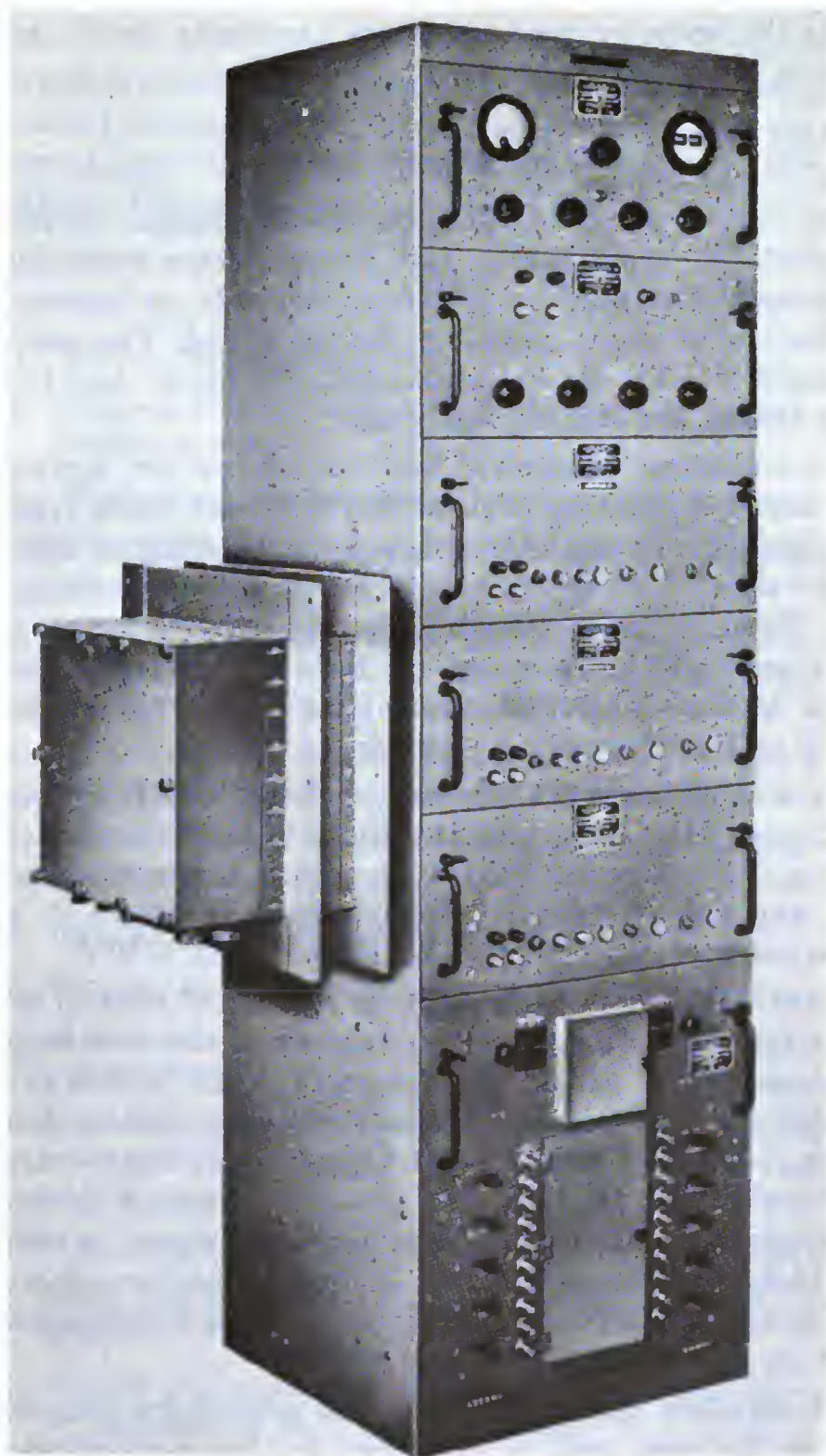


Figure 10-9.—UM switching equipment.

warns the operator not to use this particular set of stations in obtaining a fix.

### **UM Switching Equipment**

The normal loran station equipment consists of two transmitters, either two or four timers, and a switching equipment. The number of timers depends on whether the station is single-pulsed or double-pulsed. The extra transmitter and, for a double-pulsed station, the two extra timers are standby equipment.

The switching equipment and the timers are located in a shielded room to prevent any external fields from disturbing the timers. All cables, either entering or leaving the shielded room, pass through the switching equipment. These cables include those to the receiving antenna, to the source of primary power, from the output of the timers to the transmitters, and from the output of the timers to the monitoring receiver.

The UM switching equipment performs the following functions—(1) Connecting any timer to any transmitter exciter, (2) connecting the 100-kc crystal oscillator signal from any timer to the monitoring receiver where it is compared with the primary standard station WWV.

Power switches in the switching equipment control all power supplied to the timing equipment, to the switching equipment itself, and to the lighting circuits within the shielded room. The UM (figure 10-9) also isolates the timers from stray external r-f fields which might enter the shielded room through the power or antenna cables. A discriminator unit attenuates the local signal, which is initially much greater than the signal from the remote station, and roughly balances the two signals before passing them to the receiver in the timer.

The entrance box on the left-hand side of the cabinet extends through, and is grounded to, the wall of the



shielded room. All equipment in the shielded room and all coaxial cables have their common ground at the entrance box as does the elaborate grounding system used throughout the UM equipment.

## QUIZ

1. What is the purpose of loran?
2. Why can fixes be obtained at greater distances from the loran stations at night?
3. What advantages does loran have over celestial fixes?
4. Which station in a loran pair establishes the pulse repetition rate?
5. What name is given to the time interval between the transmission of a pulse from the master station and the transmission of a pulse from the slave station?
6. If the basic time delay between a master station and a slave station changes, at which station is this condition corrected?
7. How is it possible to obtain two lines of position that intersect by using only one master station and two slave stations?
8. How many loran channels are there?
9. How can all loran stations operate on a few channels?
10. A basic pulse recurrence rate is divided into how many specific pulse recurrence rates?
11. On a loran chart how are the lines of position for one pair of stations distinguished from the lines of position for another pair of stations?
12. When must the TDP-1 transmitter have two exciter units?
13. What type of oscillator circuit is used in the TDP-1 transmitter?
14. What is the purpose of the resistors in the plate return of the oscillator in the TDP-1 transmitter?
15. How are pulses at the pulse repetition rate generated in the UE-1 timer?

16. If the stations in a loran pair get out of synchronization, what indication is provided by the UE-1 timer?
17. Why are the switching equipment and timers located in a shielded room?
18. What cables pass through the switching equipment?
19. What is the purpose of the discriminator unit in the UM switching equipment?



## **LORAN RECEIVING EQUIPMENT**

### **RECEIVER UNIT IN THE DAS-4**

The model DAS-4 receiver-indicator is one type of loran set which may be installed aboard ship. The signals from the master and the slave stations are displayed on the indicator cathode-ray tube. A photograph of the DAS-4 is shown in figure 11-1. The indicator unit is the unit containing the cathode-ray tube. The receiver is to the left of the indicator.

The receiver in the DAS-4 is a conventional super-heterodyne type except that it has no variable tuning. Instead the receiver is preset to four different frequencies corresponding to the four loran channels. The channels are selected by means of a channel switch located on the front panel of the receiver. A schematic diagram of the receiver is shown in figure 11-2.

The signal from the antenna is developed across the resonant tank in the grid circuit of the r-f amplifier. The channel switch connects the correct antenna, mixer, and oscillator coils for the selected channel. Coils not in use are grounded by various sections of the channel switch. The antenna coil selected and capacitor C305 form a resonant tank circuit in the grid of the r-f amplifier. Two wave traps in the r-f amplifier grid circuit reject signals on or near the intermediate frequency of the receiver.

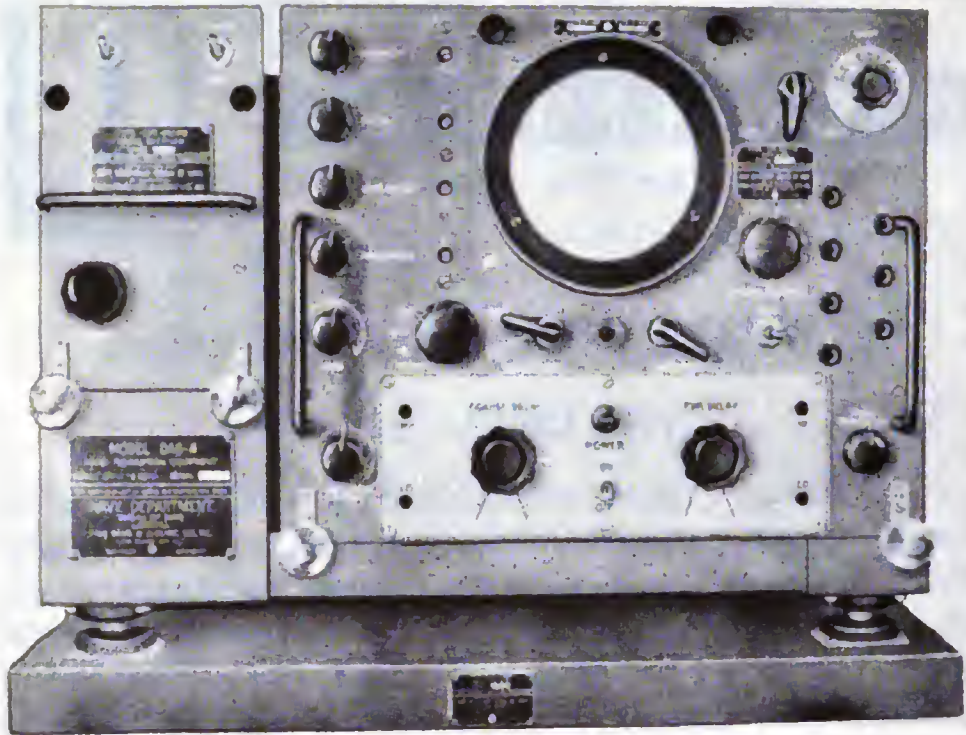


Figure 11-1.—DAS-4 receiver-indicator.

The parallel wave trap, C301 and L305, presents a high impedance to signals of 1050 kc, which is the intermediate frequency of the receiver. The series wave trap, C302 and L306, presents a low impedance to ground for any 1050-kc signal that may leak through the parallel trap. The output of the r-f amplifier is fed through a coupling capacitor to the grid of the mixer. Another series trap is placed between the signal grid and ground of the mixer.

The cathode returns from the r-f amplifier, the mixer, the first i-f amplifier, and the second i-f amplifier are connected to a common circuit which is in series with the GAIN CONTROL located in the indicator unit. The mixer stage is conventional in design. The local oscillator is a Colpitts oscillator tuned 1050 kc above the incoming signal.





The output of the mixer is amplified by three i-f amplifiers before being fed to a diode detector V306 (pins 3 and 8). The output of the detector is developed across the diode load resistor R319. Filter switch S302 is shown in the OUT position on the diagram. The filter may be switched into the circuit to reduce the effects of interference. The other half of the detector tube V306 (pins 4 and 5) is used to eliminate the positive overshoot at the grid of V307 which would result from differentiator action of the coupling circuit, especially when the filter is used. The output of the video amplifier is coupled through a capacitor and a choke to the vertical deflection plates of the cathode-ray tube. A TEST-OPERATE SWITCH is provided so that the output of a counter circuit in the indicator can be connected to the input of the video amplifier. This is done to obtain a pattern on the indicator scope so that the counter feedback circuit may be adjusted correctly.

The AMPLITUDE BALANCE CONTROL located in the indicator adjusts the gain of the third i-f amplifier. The cathode follower is part of the amplitude-balance circuit. This circuit is needed to equalize the signals from the master and from the slave stations. The signal from one of these stations may be larger than the signal from the other and to match the pulses on the screen of the indicator it is necessary that the amplitude of the two signals be the same. The amplitude-balance circuit is described in greater detail later in this chapter.

## OPERATION OF THE DAS-4 INDICATOR UNIT

The indicator is used to measure the time difference between a pulse from the master station and a pulse from a slave station operating on the same PRR. The signal from the master station appears on one trace. The signal from the slave station appears on the other trace, as

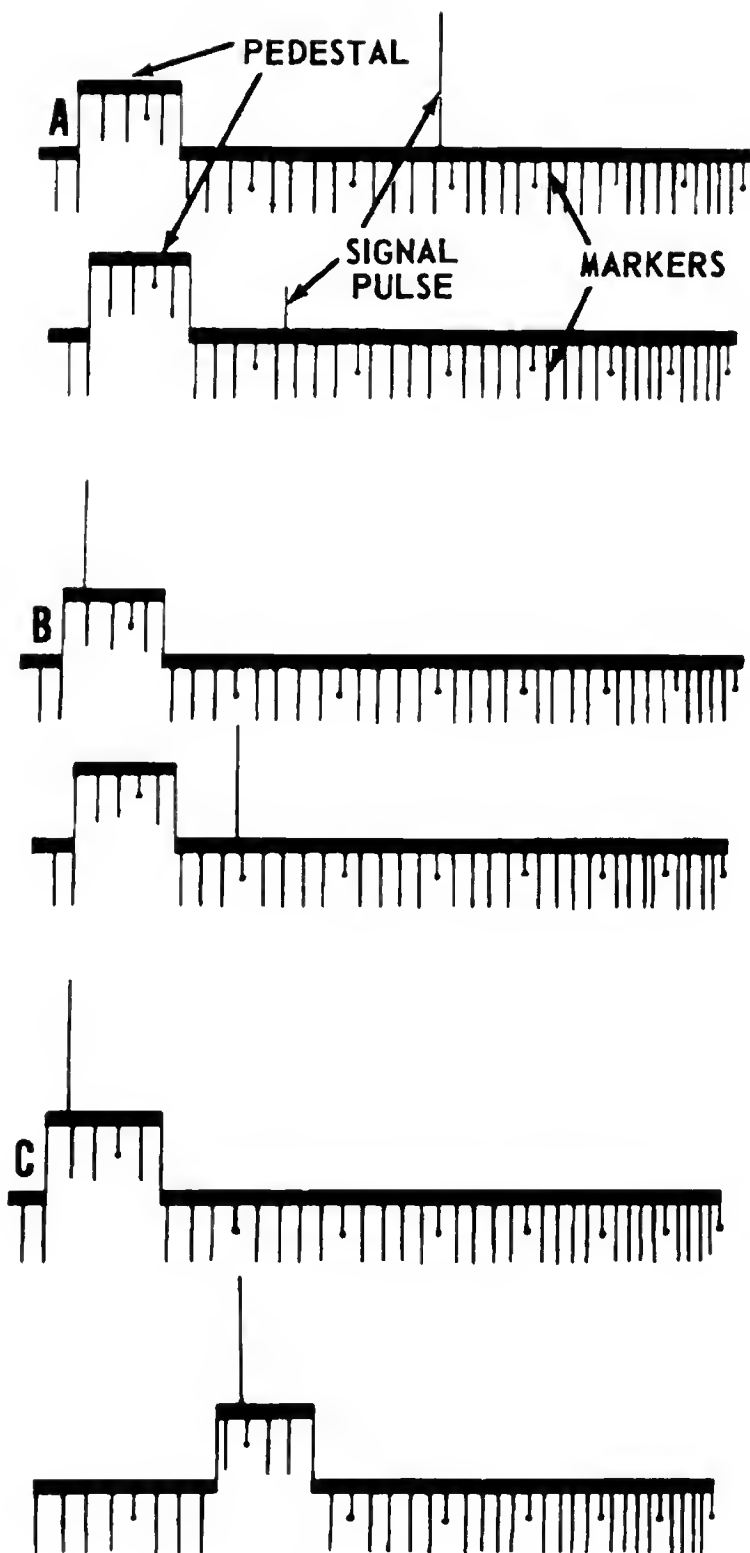


Figure 11-3.—Signals appearing on the indicator. A, Before adjustment of the amplitude balance control, B, after adjustment of the amplitude balance control, C, pulses placed on the pedestals.

shown in figure 11-3. This pattern appears when the sweep speed switch is set at SLOW, the fast sweep switch at 3, and the receiver switch at its ON-1 position. The markers appearing downward from the traces are at 500-microsecond intervals. Every fifth marker is made shorter for ease in counting. After selecting the channel, the basic PRR, and the specific PRR, the signals may appear anywhere along the traces as shown in figure 11-3, A. The master station pulse is always to the left of the slave pulse. Thus, in figure 11-3, A, the master pulse is on the lower trace.

The amplitude balance control is adjusted until the amplitudes of the two pulses are equal, as shown in figure 11-3,B. Then by using the LEFT-RIGHT switch, the pulses are moved along the traces until the pulse from the master station is on the upper pedestal (figure 11-3,B). The COARSE DELAY and the FINE DELAY controls are now used to move the pedestal on the lower trace until the slave signal appears on the lower pedestal as shown in figure 11-3,C.

When the SWEEP SPEED is turned to FAST, the tops of the pedestals enlarge until they cover the entire width of the screen (figure 11-4,A). To obtain this pattern the sweep speed switch is set at FAST, and the fast sweep switch at 3. The delay controls are then adjusted until the slave pulse appears directly under the master pulse. The pulses are moved by the left-right switch until they are within the first 500-microsecond interval at the left end of the screen (figure 11-4,B).

The left ends of the traces up to the first 500-microsecond marker are made to cover the full width of the screen by changing the FAST SWEEP switch to position 2 (figure 11-5). The slave pulse is brought under the master pulse by using the fine-delay control. The pulses are moved to the left ends of the traces by the left-right switch. Turning the fast-sweep switch to position 1

enlarges the portions of the traces appearing to the left of the fourth 50-microsecond marker. The pulses appear in a pattern similar to that shown in figure 11-6.

Moving the receiver (RECVR) switch to the ON-2 position eliminates the trace separation and the markers. The two pulses appear to be on the same trace as shown in figure 11-7. For this pattern the sweep-speed switch is set at FAST, and the fast-sweep switch at 1 (figure 11-7,A).

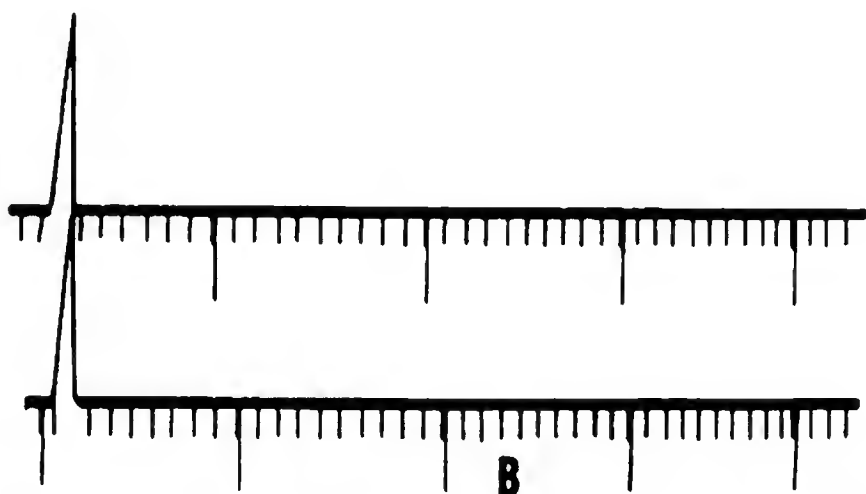
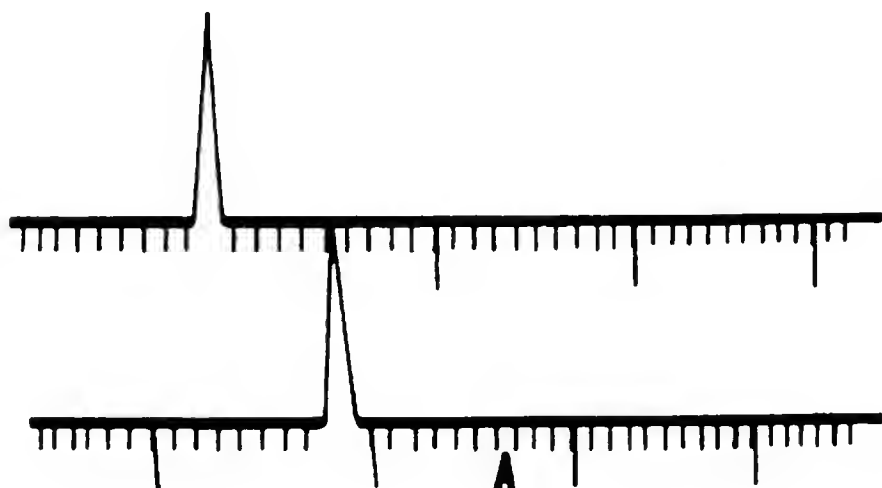
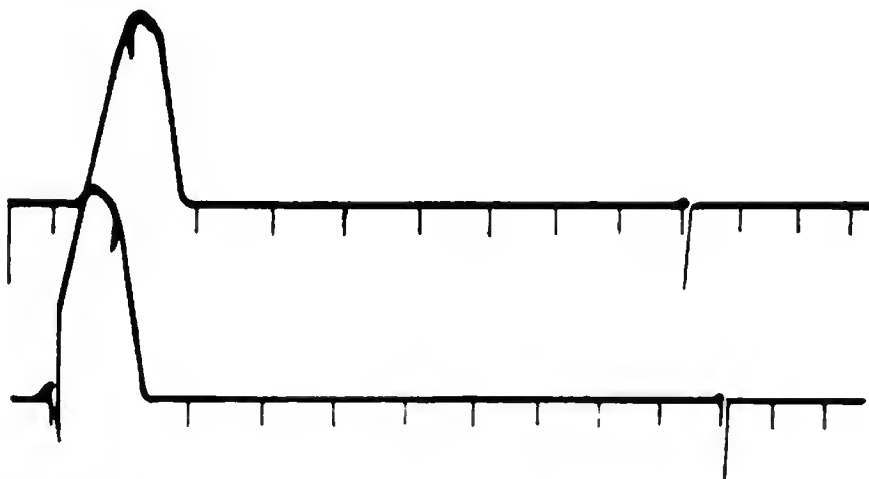


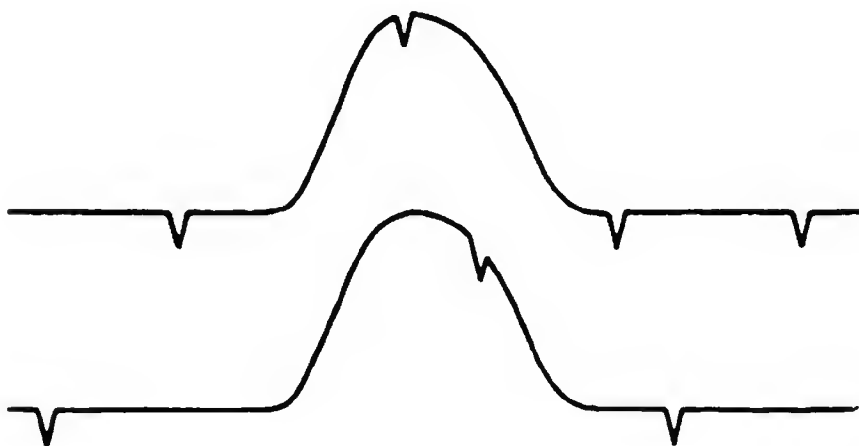
Figure 11-4.—Aligning the master and slave pulses. A, Pulses roughly aligned; B, pulses aligned and moved to the left end of the traces.



The two pulses are then superimposed (figure 11-7,B) by adjusting the fine-delay control. The pulses will not coincide exactly. Correct adjustment is reached when the leading edges of the two are matched. After the pulses



**Figure 11-5.—Pulses appearing on the indicator when the sweep speed switch is at FAST and the fast sweep switch is at position 2.**



**Figure 11-6.—Pulses appearing on the indicator when the sweep speed switch is at FAST, and the fast-sweep switch is at position 1.**

have been superimposed, the delay controls must not be disturbed until the time difference is read.

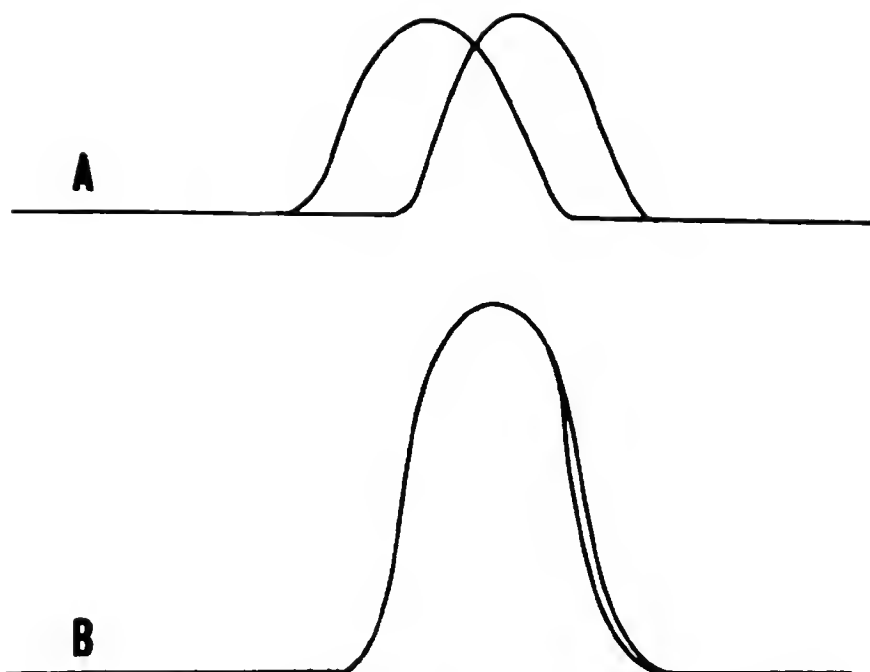
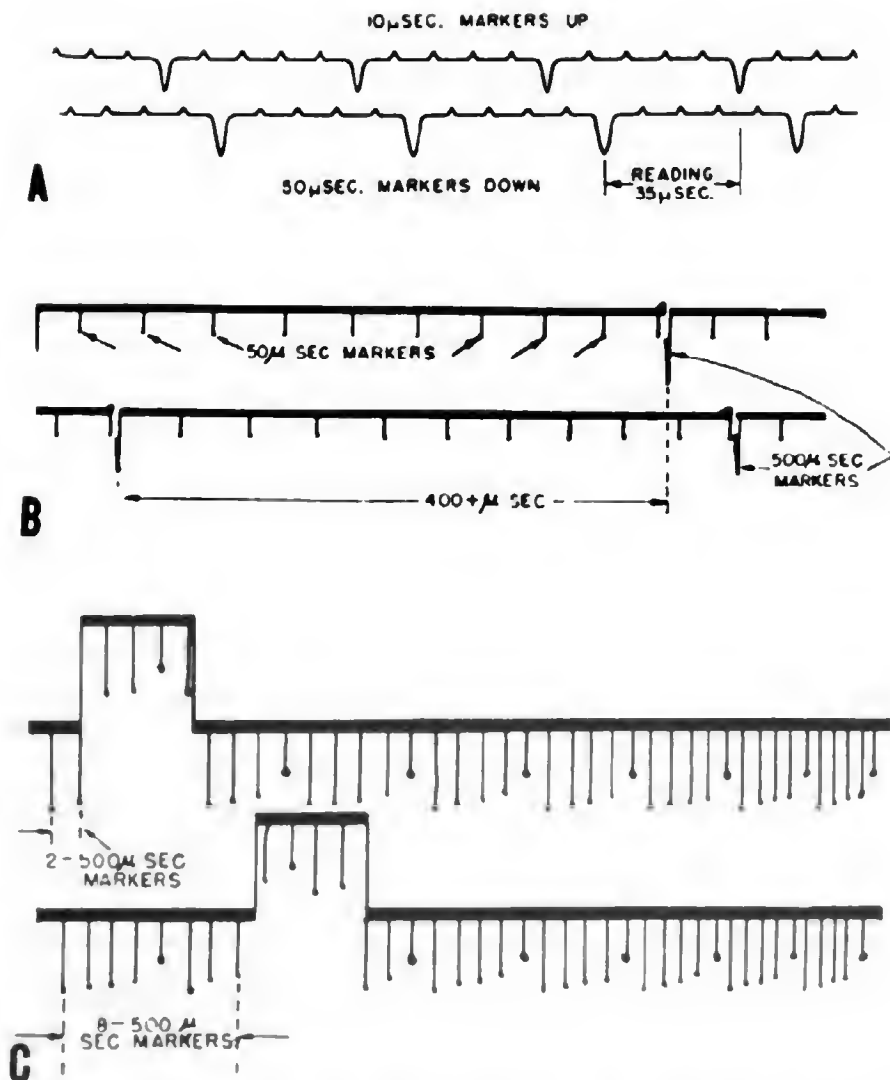


Figure 11-7.—Matching the pulses. A, Upper and lower traces superimposed, B, both traces and pulses superimposed.

The time difference reading is made in three steps. The controls are left in the same position as they were for superimposing the pulses, with the exception that the receiver switch is moved to the OFF position. The pattern shown in figure 11-8,A, will appear. From one of the downward projecting 50-microsecond markers on the lower trace count the number of microseconds to the right of this marker to a point directly below the next 50-microsecond marker on the upper trace. The small upward markers are at 10-microsecond intervals. The reading is 35. This completes the first step.

Next turn the gain control to its extreme counterclockwise position and the fast-sweep switch to position 2. Place the receiver switch at its ON-1 position. Turn the TRACE SEPARATION control until the traces are about half an inch apart. The pattern on the indicator will be similar to the one shown in figure 11-8,B. Count the number of



**Figure 11-8.—Reading the time difference. A, Reading 35 microseconds, B, reading 400 microseconds, C, reading 3,000 microseconds.**

50-microsecond markers from the right side of the 500-microsecond marker on the lower trace to a point directly beneath the 500-microsecond marker on the upper trace. In figure 11-8,B, there are eight 50-microsecond markers so the reading is 400 microseconds. This completes the second step.

The pattern shown in figure 11-8,C, is obtained when the sweep-speed switch is set at SLOW and the fast-sweep

switch is turned to position 3. Count the number of 500-microsecond markers to the left of the pedestal on the lower trace. In figure 11-8,C, the number is 8. The corrected reading is taken from the left edge of the upper pedestal to the left edge of the lower pedestal. Since the upper pedestal's left edge is always fixed at the second marker on the upper trace, two markers must be subtracted from the number counted on the bottom trace. In figure 11-8,C, the reading is 6, which corresponds to

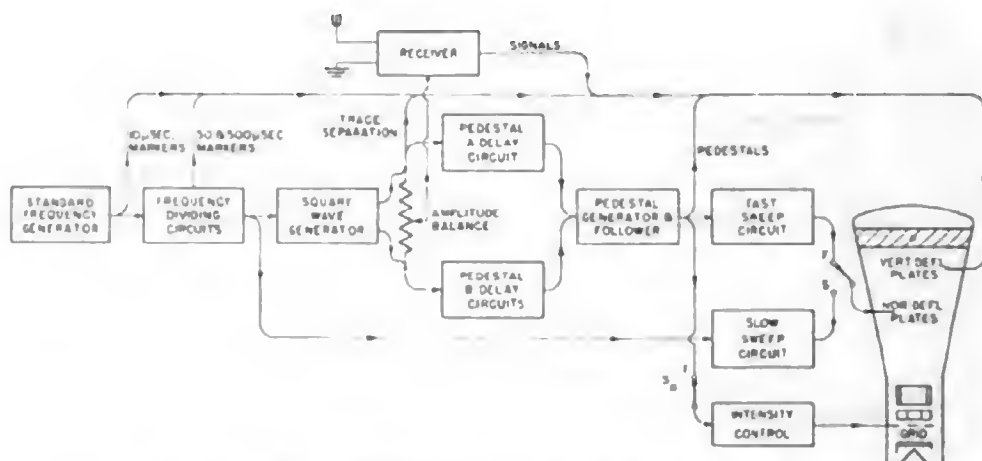


Figure 11-9.—Simplified block diagram of the DAS-4.

3000 microseconds. This completes the third step. Adding the readings obtained in the three steps gives a total time difference of 3435 microseconds.

## DAS-4 INDICATOR CIRCUITS

The output of a standard frequency generator, 100,000 cycles per second, is divided by a series of counter circuits to produce pulses of 50 to  $50\frac{7}{8}$  cycles per second (in  $\frac{1}{8}$ -cycle steps) and  $66\frac{2}{3}$  to  $68\frac{2}{9}$  cycles per second (in  $\frac{2}{9}$ -cycle steps). These pulses correspond to twice the PRR of corresponding pairs of loran stations. Pulses from the counter circuits are used for markers and for tripping

various other circuits. A simplified block diagram of the DAS-4 is shown in figure 11-9.

Through a phase-shifting circuit a portion of the 100,000-cycle signal is used to produce 10-microsecond markers. The phase-shifting circuit is used to cause every fifth 10-microsecond marker to coincide with the 50-microsecond markers. One cycle of the output of the standard frequency generator corresponds to 10 microseconds. The 100,000-cycle signal is amplified and clipped in the 10-microsecond marker circuit. The clipped signal is applied between the upper vertical deflection plate of the cathode-ray tube and ground.

Output pulses from the last counter circuit start the slow-sweep circuit which provides a horizontal sweep at exactly twice the transmitter PRR. A square-wave generator, also tripped by the last counter, provides a square wave at half the sweep frequency. The square wave vertically displaces alternate horizontal sweeps to produce two horizontal traces one above the other.

The square wave is applied between the lower vertical deflection plate of the cathode-ray tube and ground. The output of the square-wave generator trips the *A*- and *B*-delay circuits. The letters "A" and "B" refer to the delays affecting the upper and lower traces, respectively. The delay circuits introduce a time delay between the beginning of the trace and the beginning of the pedestal.

The *A*-delay is fixed while the *B*-delay is variable over a range of approximately 10,000 microseconds. A pedestal-generator circuit produces a pedestal on each trace. The pedestal can assume any one of three different horizontal lengths. These lengths correspond to 225, 750, and 2500 microseconds, depending on the position of the fast-sweep switch. When the sweep-speed switch is set at FAST, the pedestal generator trips the fast-sweep circuit to expand the top of the pedestal to the full width of the screen.



A small capacitor from the plate to grid together with the grid-plate capacitance of the tube supplies positive feedback. Capacitor C104 is the DRIFT CONTROL. The frequency of the oscillator can be varied  $\pm 30$  cycles with this control in order to bring the oscillator into synchronism with the transmitting stations. Switch S105A is a section of the left-right switch. Moving this switch causes the indicator circuits to go out of synchronism

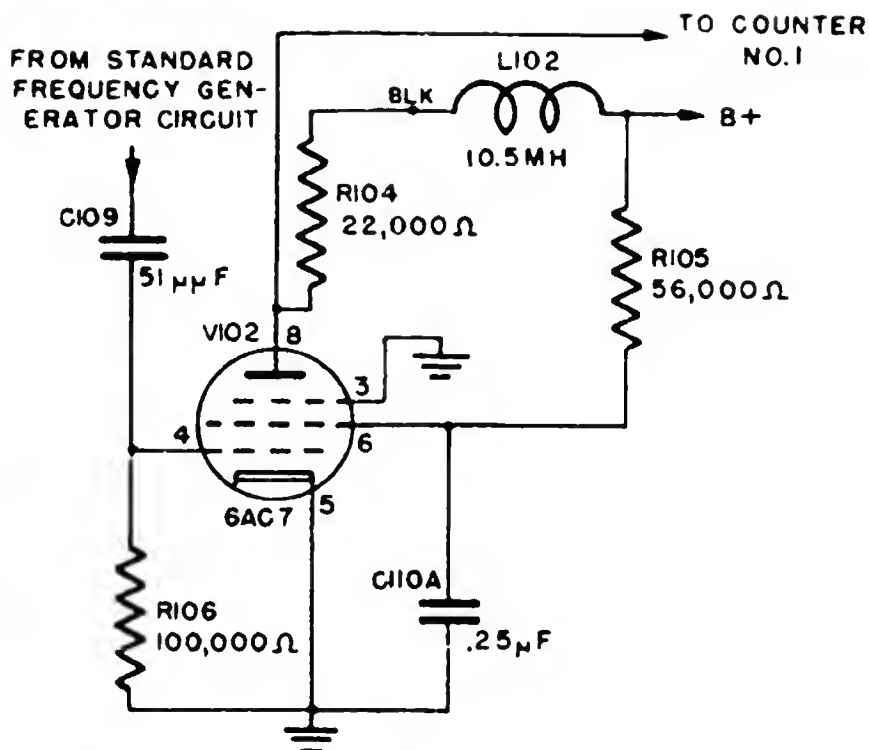


Figure 11-11.—Schematic diagram of the squaring amplifier.

temporarily so that the pulses can be moved along the traces. The plate tank is composed of capacitor C213 and the primary of transformer T101. The plate tank is tuned to 115 kc. The secondary of the transformer is part of the 10-microsecond marker circuit.

### Squaring Amplifier

The output of the standard frequency generator is fed to the squaring amplifier (figure 11-11). This stage is an overdriven amplifier being driven alternately into cutoff and saturation by the sine-wave output of the generator. The output of the squaring amplifier is a square wave used to trip the first counter circuit.

### Counter Circuits

A schematic diagram of the first counter circuit is shown in figure 11-12. All the counter circuits in the

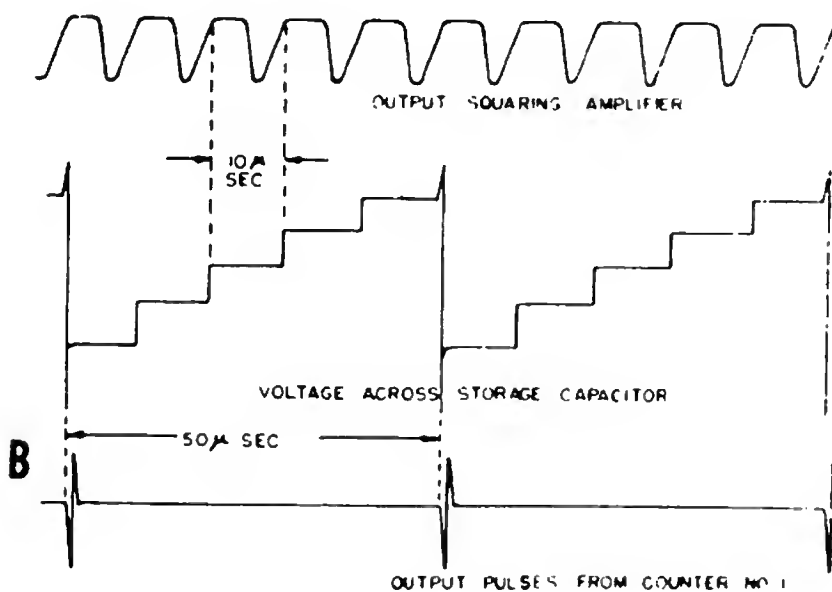
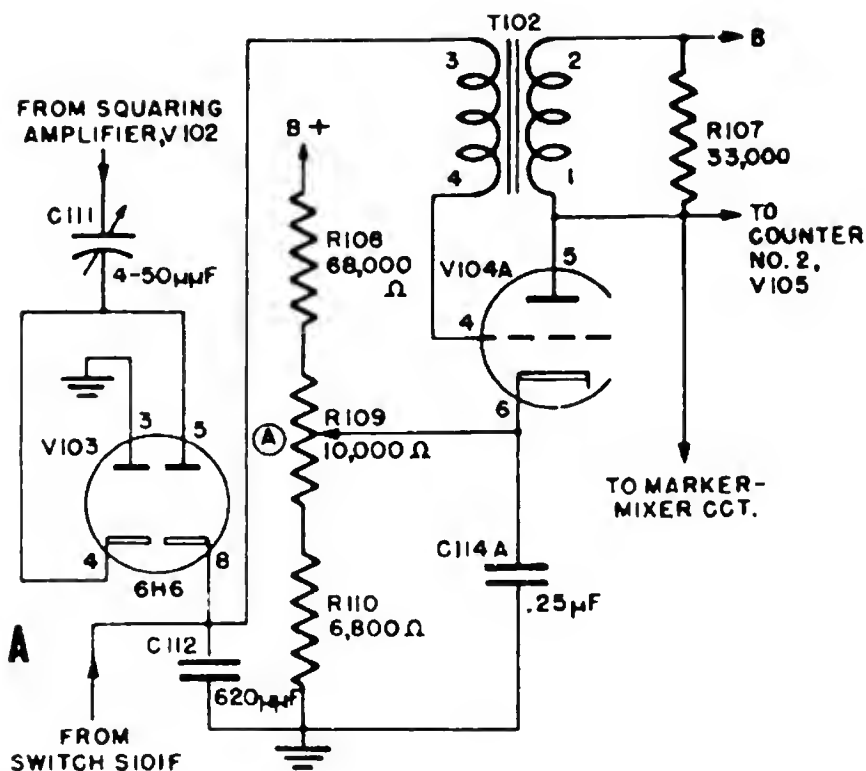


Figure 11-12.—Counter no. 1. A, Schematic diagram, B, waveforms.



DAS-4 operate in a similar manner. A counter of the type used in this equipment is essentially a combined blocking oscillator and voltage-accumulator tripping circuit. The output of the squaring amplifier drives counter no. 1. Small positive and negative pulses of current from the output of the squaring amplifier pass through the variable capacitor C111. The output of the squaring amplifier (figure 11-12,B) is coupled through capacitor C111 to the diodes. The negative pulses from the squaring amplifier are shunted to ground through the left-hand diode. The positive pulses cause the right-hand diode to conduct and charge capacitor C112. Each time the right-hand diode conducts, the voltage across C112 increases by about 10 volts (figure 11-12,B).

The cathode of V104A has a high positive bias obtained from a bleeder network. This bias, which can be adjusted by potentiometer R109, holds V104A well beyond cutoff.

The voltage developed across C112 is connected directly from the grid of V104A to ground. When this voltage is great enough it will overcome the positive bias on the cathode of V104A and cause this tube to conduct. In normal operation five positive pulses from the squaring amplifier are required for the voltage across C112 to overcome the bias on V104A.

When V104A conducts, there is a sharp increase in plate current which induces a voltage across the grid winding of the transformer. The voltage induced in the grid circuit drives the grid more positive and increases the plate current. In a very short time the tube becomes saturated. The sharp increase in plate current is accompanied by a surge of grid current which discharges capacitor C112. The transformer field stops rising when the tube saturates and the grid swings in a negative direction. Plate current falls and the collapsing field induces a voltage in the grid winding, which drives the tube beyond cutoff. During the interval when grid current

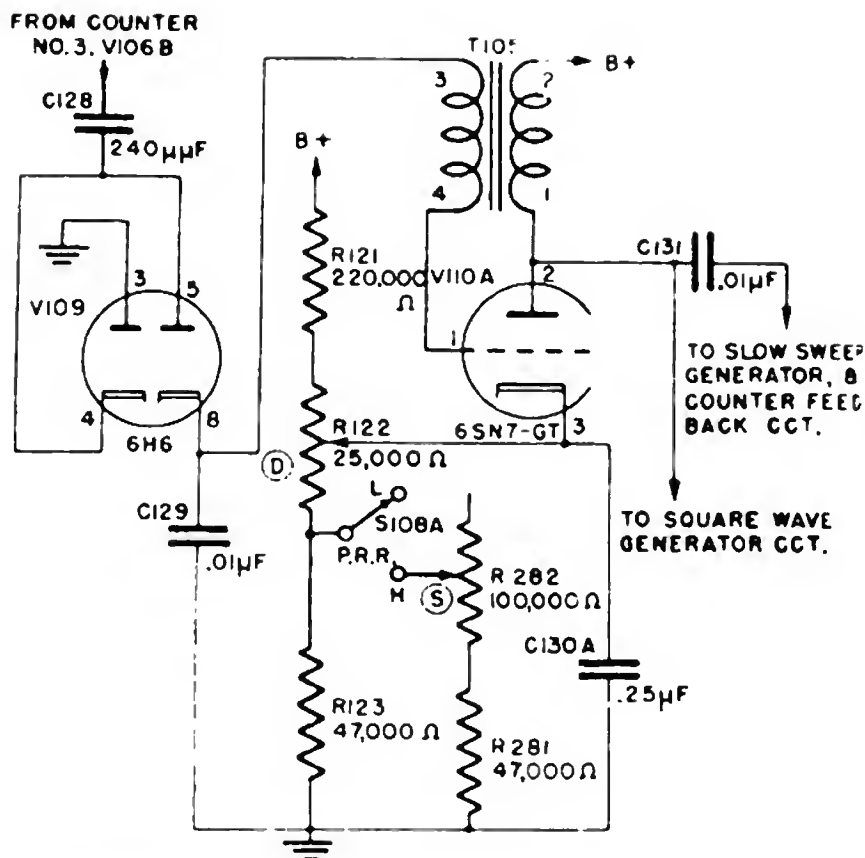


Figure 11-13.—Schematic diagram of the fourth counter.

flows, capacitor C112 charges in the opposite direction and its negative voltage is impressed on the grid of the triode at the instant it stops conducting. This charge is removed very rapidly by conduction of the two halves of the diode in series. The pulses appearing in the plate circuit of the triode are an exact submultiple of the input pulses.

Changing the bias on the triode with potentiometer R109 changes the number of input pulses needed to overcome this bias. Therefore, adjusting R109 changes the number of input pulses needed for one output pulse from the triode. The potentiometer is correctly adjusted when five input pulses produce one output pulse.

The second and third counters are similar to the first

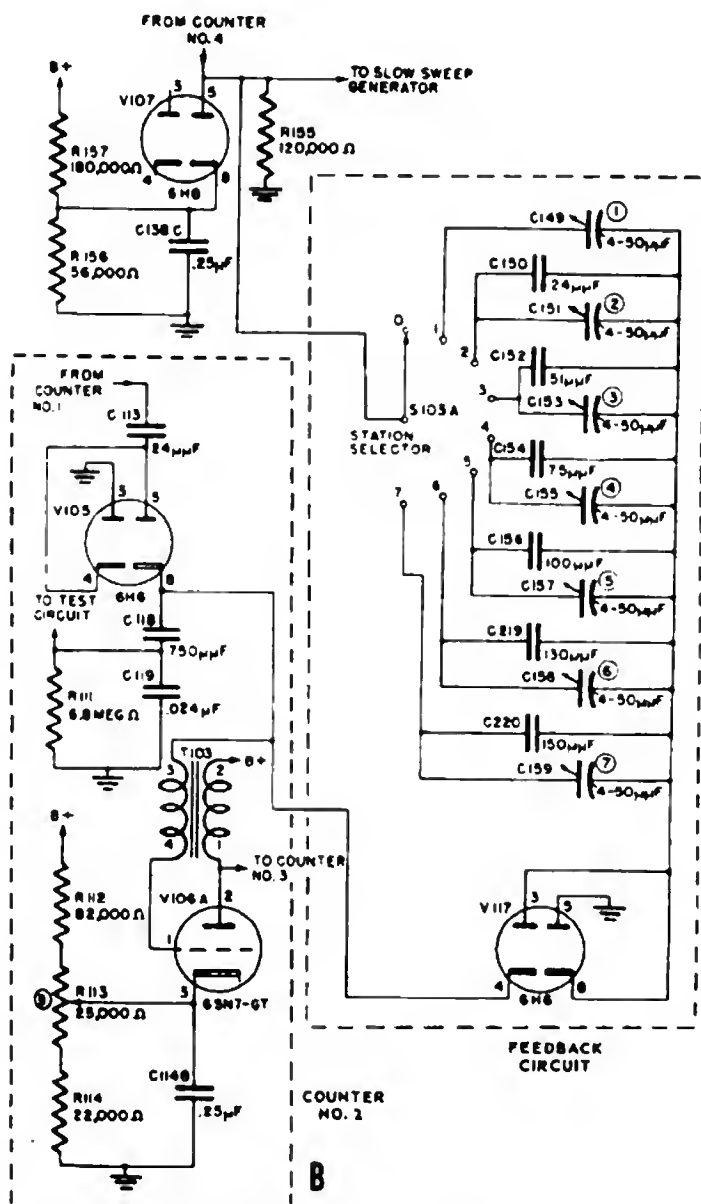
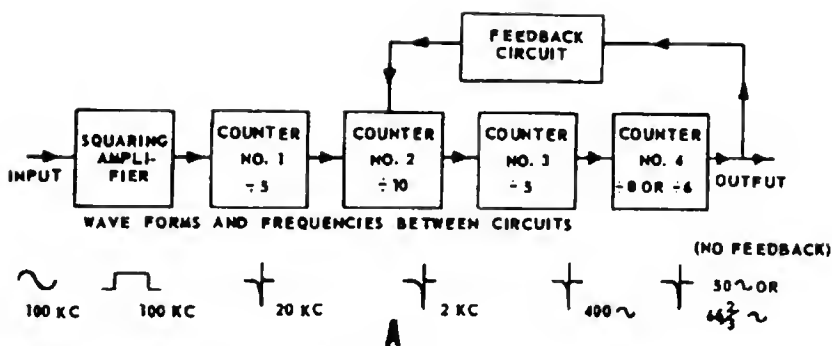


Figure 11-14.—Counter and feedback circuits. A, Block diagram; B, schematic.

counter. The second counter requires 10 pulses from the first counter for one output pulse. And the third counter requires 5 pulses from the second counter for one output pulse, with no feedback. Therefore, to get one output pulse from the third counter 250 pulses from the squaring amplifier to the first counter are needed.

The bias arrangement used with the fourth counter is somewhat different from that used in the other counters. A schematic diagram of the fourth counter is shown in figure 11-13.

The number of input pulses for each output pulse is determined by the position of the PRR switch. When this switch is in the L (low) position, the cathode bias from the bleeder is such that 8 pulses raise the grid voltage enough for the triode to conduct. If the switch is changed to the H (high) position, the cathode bias is reduced and 6 input pulses cause the triode to conduct. The output of the fourth counter trips the square-wave and slow-sweep generators and supplies feedback to the second counter.

### Counter Feedback Circuit

Without feedback, to produce one output pulse from the fourth counter requires 400 pulses input to the second counter, provided the PRR switch is at L, and 300 pulses if this switch is at H. The counter feedback circuit provides a means of reducing the number of input pulses to the second counter for each output pulse of the fourth counter. A block diagram indicating the relation between the counter feedback circuit and the four counter circuits is shown in figure 11-14, A. Depending on the setting of the PRR switch, the reduction will be either from 400 to 393 pulses, or 300 to 293.

The pulses fed back to the second counter from the fourth counter are impressed across limiter V107 (figure 11-14, B). Tubes V105 and V106A with their associated

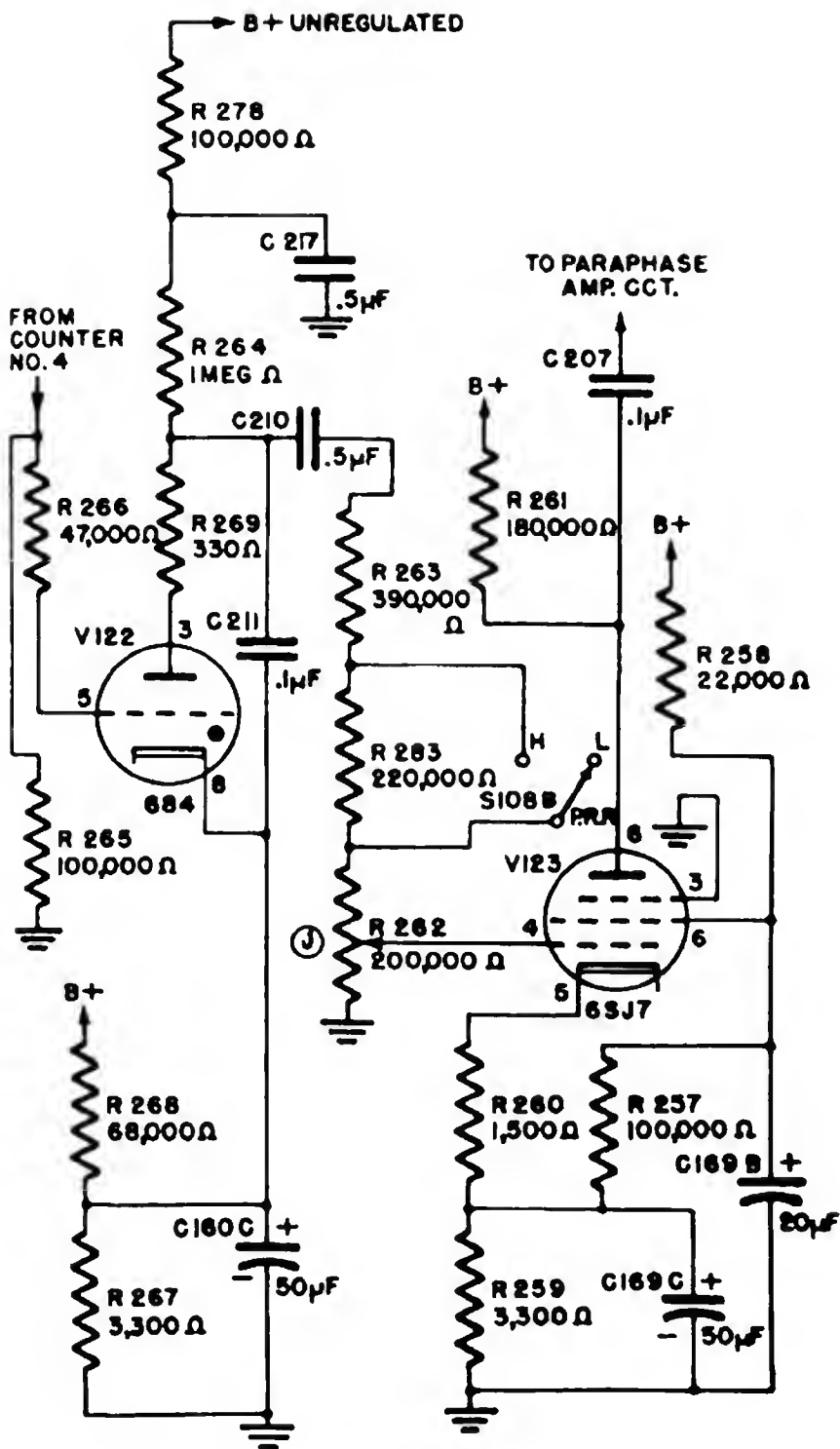


Figure 11-15.—Schematic diagram of the slow-sweep circuit.

components form the second counter circuit. Limiter V107 keeps the input voltage to the feedback capacitors (1 through 7) constant. The limiter is biased from a bleeder R156. This bias makes the cathode positive with respect to the plate. However, if the positive portion of the output pulse from the fourth counter exceeds this bias, the diode conducts and limits the pulse amplitude. The negative portion of the pulse is shunted to ground by the right-hand section of V117. The position of the STATION SELECTOR switch S103A determines the amount of feedback voltage. Changing the position of the station selector switch changes the value of capacity placed in series with the left-hand section of V117.

The voltage on triode V106A is the voltage developed across capacitors C118 and C119. With no feedback, 10 pulses from the first counter are required to cause the triode to conduct. The fourth counter output consists of one pulse in every 20,000 microseconds (50 cps) without any feedback, when the PRR switch is in the L position.

Each output pulse from the fourth counter will be fed back through the station selector switch to capacitors C118 and C119 as input to the second counter. The magnitude of the voltage which this pulse places across these capacitors depends on the switch position. Suppose that the station selector switch is in position 3. In this case the voltage on capacitors C118 and C119 will be equal to that produced by three pulses from the first counter. Since a total of 10 input pulses to the second counter produce one output pulse therefrom only 7 pulses from the first counter are now required to produce one output pulse from the second counter.

Every time the station selector switch is advanced a step toward position 7, the number of pulses necessary from the first counter to trip the second counter is reduced by one. This reduces the recurrence rate of the fourth counter by 50 microseconds. With the station

selector switch in position 3 the reduction is 150 microseconds. Now, instead of having a pulse every 20,000 microseconds (50 cps) from the fourth counter the pulse will occur every 19,850 microseconds ( $50 \frac{3}{8}$  cps). The small trimmer capacitors are used to adjust the amount of feedback for each position of the station selector switch.

### Slow-Sweep Circuit

The slow-sweep circuit includes a sweep generator and an amplifier. A schematic diagram of this circuit is shown in figure 11-15. The slow-sweep generator provides a horizontal sweep voltage to the cathode-ray tube at exactly twice the recurrence rate of the loran transmitting stations. The beginning of the sweep is controlled by the output of the fourth counter.

Tube V122 is a conventional thyatron sweep generator. Assume that the tube is not conducting. Capacitor C211 charges through resistor R264. If no pulses from the counter are placed on the grid of the thyatron, the capacitor charges to about 140 volts before the thyatron fires. When the thyatron fires, capacitor C211 discharges to about 50 volts before the tube deionizes. The frequency of the sweep in this case is determined by the time constant of R264 and C211. Since capacitor C217 has five times the capacity of C211, it acts as a battery to charge C211.

The grid of the thyatron is driven positive by pulses from the fourth counter. These pulses start the tube conducting before capacitor C211 has time to charge to the firing potential determined by the cathode bias alone. Therefore the circuit synchronizes with the output pulses from the fourth counter. The duration of the saw-tooth waveform, including the retrace time, is the same as the interval between output pulses from the fourth counter.

The saw-tooth is coupled to the grid of sweep amplifier

V123. The amplitude of the voltage applied to the grid is adjusted by potentiometer R262. When the PRR switch is changed to the H position, one of the grid resistors is shorted-out in order to provide a higher saw-tooth voltage on the grid. This is done to keep the length of the sweep the same for either position of the PRR switch.

The output of the slow sweep amplifier is fed to a paraphase amplifier when the slow sweep is being used. The output of the paraphase amplifier is fed to the horizontal deflection plates of the cathode-ray tube.

### **Square-Wave Generator**

The square-wave generator is an Eccles-Jordan multivibrator. As shown in the schematic diagram (figure 11-16,A) the circuit is symmetrical. The circuit is connected so that an increase in plate current of one triode causes a decrease in the plate current of the other triode.

Assume that V115A is conducting and V115B is cut off. An output of the fourth counter is coupled to the cathode of V110B, which is connected as a diode. This tube conducts only when a negative pulse is placed on its cathode. Therefore, only negative pulses can be coupled to the grids of the triodes. A negative pulse has no effect on V115B because it is already cut off.

However, the same negative pulse is applied also to the grid of V115A, which is conducting. This negative pulse reduces the plate current of V115A, causing its plate voltage to increase. The increase in plate voltage is coupled through capacitor C167 and resistor R180 to the grid of V115B. This causes V115B to start conducting; its plate voltage drops and the drop is coupled to the grid of V115A, causing this tube to cut off. V115B continues to conduct until another negative pulse from the counter cuts it off and causes V115A to conduct. The triodes have equal on and off periods (figure 11-16,B).





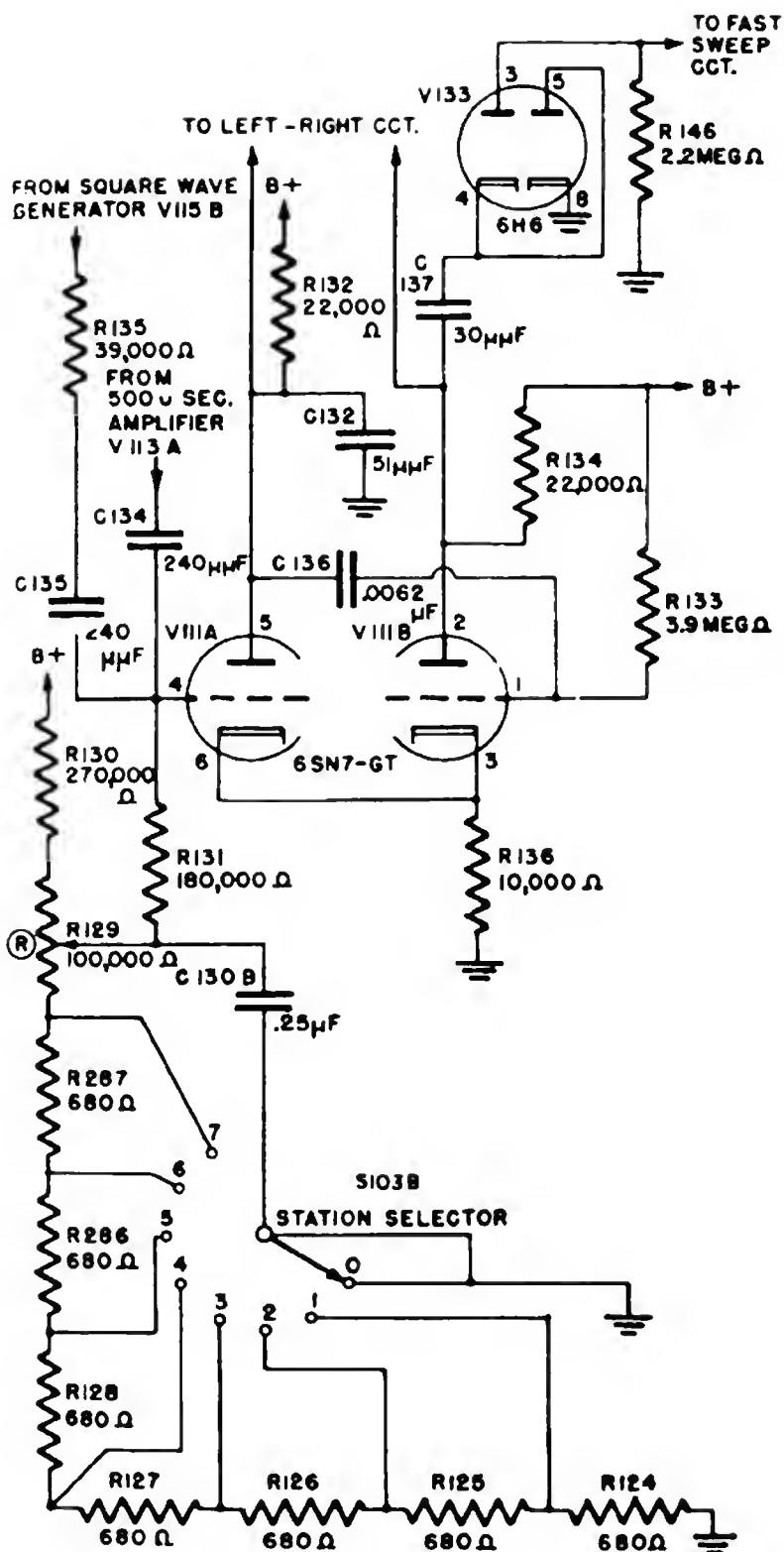


Figure 11-17.—Schematic diagram of the A-delay circuit.

Their output is therefore a square wave. The square-wave generator supplies outputs to the amplitude-balance circuit and to the delay circuits.

### A-Delay Circuit

The positions of the pedestals on their respective traces are determined by the time-delay circuits. The delay associated with the upper trace is designated the *A-DELAY* and the one for the lower trace, the *B-DELAY*. The square wave from the square-wave generator is differentiated to produce sharp pulses which trigger the delay circuits. The differentiated positive pulses trip the *A-* and *B-*delay circuits on alternate horizontal sweeps. The differentiated negative pulses have no effect on the delay circuits. The outputs of both delay circuits are mixed and used to trip the pedestal generators.

The *A*-delay circuit introduces time delay between the beginning of the upper trace and the beginning of the *A-PEDESTAL*. On the next horizontal sweep after the *A*-pedestal generator is tripped, the *B*-delay circuit introduces a time delay between the beginning of the lower trace and the beginning of the *B-PEDESTAL*. The time delay introduced by the *A*-delay circuit is fixed while the time delay of the *B*-delay circuit is variable over the range of approximately 1000 to 10,000 microseconds.

The *B*-delay is obtained from two multivibrators. The first multivibrator is called the *B1*-delay circuit and contains the coarse delay control. This delay circuit operates in steps of 500 microseconds. The second multivibrator is called the *B2*-delay circuit and contains the fine delay control. By using the fine delay control a time delay between 0 and 650 microseconds may be introduced into the circuit. The delays in the two multivibrator circuits add, since the multivibrators are connected in series.

The *A*-pedestal delay multivibrator (figure 11-17) receives a differentiated positive pulse from the square-

wave generator. This positive pulse trips the delay circuit at the same time as the beginning of the upper trace on the cathode-ray tube. The multivibrator sends a negative pulse to the pedestal generator at the end of a definite period of time. This time delay can be adjusted with potentiometer R129 in steps of 500 microseconds.

Tube V111 is connected so that V111A is normally cut off and V111B is normally conducting. The space current of V111B flows through cathode resistor R136 which is common to both tubes. The bias developed across this resistor is sufficient to cut off V111A. The grid of V111B is returned to B+ through resistor R133, which ensures that V111B conducts heavily and is normally on. The grid of V111A is biased from a voltage divider in addition to the cathode bias. The amount of bias is determined by adjusting potentiometer R129 and by the position of the station-selector switch.

When a differentiated positive pulse is placed on the grid of V111A, this tube conducts and its plate voltage drops. The drop in plate voltage causes capacitor C136 to discharge. The discharge appears as a negative voltage on the grid of V111B and cuts off this tube. Cutting off V111B reduces the current through the common cathode resistor and lowers the bias on V111A. Now V111A is conducting while V111B is cut off.

During the time V111A conducts, capacitor C136 discharges and V111B remains cut off. The discharging capacitor keeps this tube cut off. However, when C136 discharges sufficiently, V111B again conducts. The increased current through the cathode resistor increases the bias on V111A and lowers its plate current. This increases its plate voltage. The higher plate voltage causes capacitor C136 to charge up and the grid of V111B to go more positive. This further increases the cathode bias on V111A and cuts it off. The delay circuit is again normal with V111B conducting and V111A cut off.

The sharp drop in plate voltage of V111B caused by the sudden rise in plate current following the partial discharge of capacitor C136 produces an output pulse through capacitor C137. The period of time during which V111B is not conducting represents the time delay between the input pulse from the square-wave generator and the output pulse which trips the pedestal generator. It also represents the time delay between the start of the upper trace and the start of the A-pedestal. The time delay is varied by adjusting potentiometer R129. This changes the bias on the grid of V111A and determines the amount of current flowing through the cathode resistor when V111A is conducting. The potentiometer setting determines the cathode bias on V111B, when this tube is not conducting. Since the plate voltage for conduction depends on the grid bias on V111B the potentiometer setting, therefore, determines the length of time that capacitor C136 must discharge before V111B will conduct.

The time delay is locked by negative 500-microsecond markers placed on the grid of V111A. The markers appear as positive pulses in the plate circuit of V111A. They are coupled through C136 to the grid of V111B. Figure 11-18 is the waveform on the grid of V111B, when it is not conducting. The end of the time delay is established by the first 500-microsecond marker whose peak voltage raises the grid above cutoff. The output pulse is always started by a 500-microsecond marker provided the time delay is at least 500 microseconds and the locking pulses are large enough to make the total grid voltage greater than the voltage at the base of the next locking pulse.

In order to facilitate locking the circuit on the second 500-microsecond marker, the grid bias on V111A is changed slightly, when the channel selector switch is changed. The output from V111B, a square wave, is

coupled through capacitor C137 to the twin diode V133 and resistor R146. This square wave is differentiated by C137 and R146. The resistance of the series diode (pins 3 and 4), when conducting, is low and can be neglected as far as the differentiating circuit is concerned. The diode section (pins 5 and 8 of V133) shorts the positive pulses to ground. The differentiated negative pulses developed across R146 are used to trip the pedestal generator and the fast-sweep circuit.

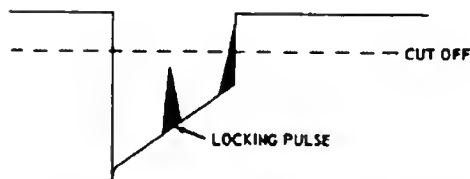


Figure 11-18.—Waveform showing the locking pulses.

### B1-Delay Circuit

The *B1*-delay circuit is similar to the *A*-delay circuit. A schematic diagram of the *B1*-delay circuit is shown in figure 11-19. Tube V114B is normally cut off and V114A is normally conducting. The grid of V114A is biased slightly positive. This ensures that the current drawn by V114A develops enough voltage across the cathode resistor to cut off V114B. A positive square wave from the square-wave generator is differentiated by C164 and R173. The positive pulse developed across R173 triggers the multivibrator. When V114B starts conducting, there is a sharp drop in its plate voltage which appears as a negative voltage on the grid of V114A and cuts off this tube.

The square wave which trips the *B1*-delay circuit is 180 degrees out of phase with the square wave that trips the *A*-delay circuit. As shown in figure 11-16, the output that trips the *A*-delay circuit is taken from the plate of V115B and the output that trips the *B1*-delay circuit is

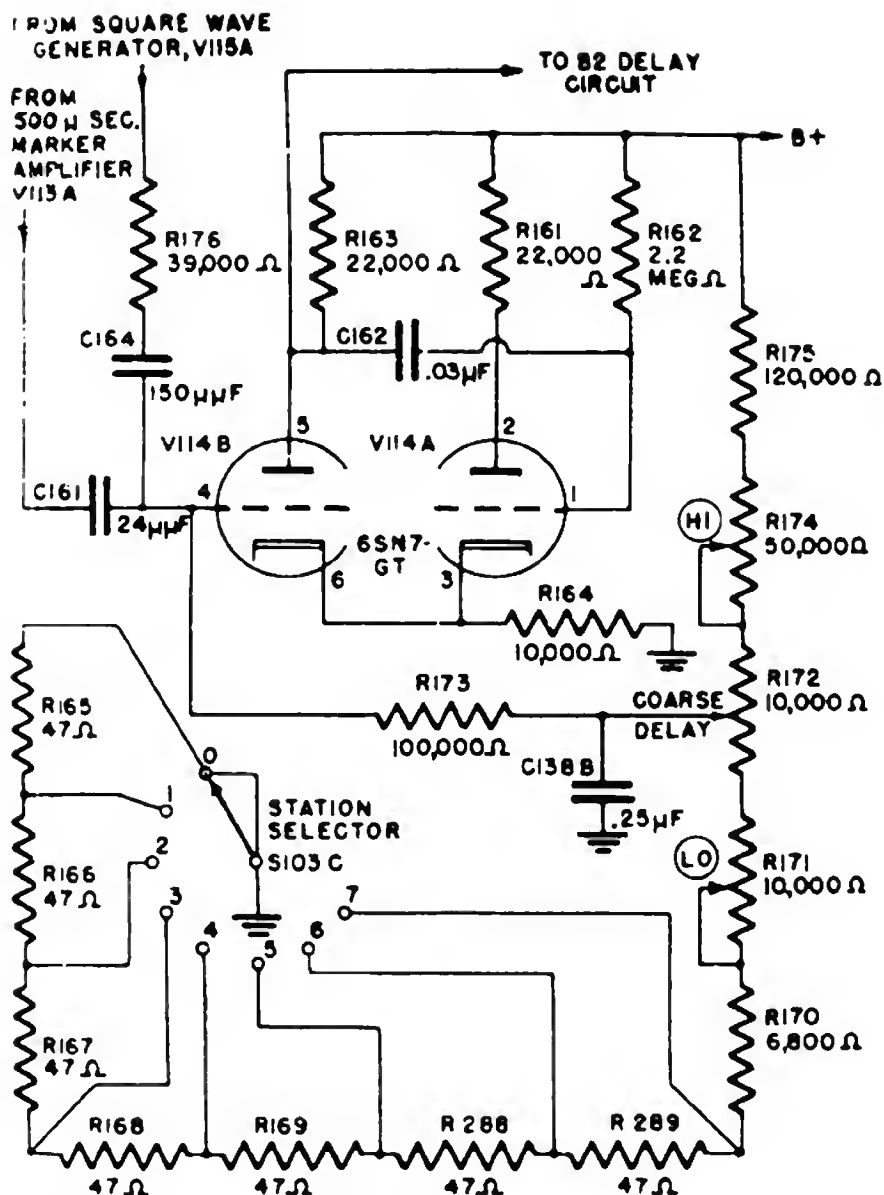


Figure 11-19.—Schematic diagram of the B1-delay circuit.

taken from the plate of V115A. A pulse from the fourth counter trips the slow sweep generator and also the square-wave generator. This starts the upper trace and also the A-delay. The next pulse from the fourth counter again trips the slow sweep generator, starts the lower trace, and begins the B1-delay.

The first pulse from the fourth counter produces a positive square wave at the plate of V115B. When differentiated this positive square wave produces a positive pulse which starts the *A*-delay. At the same time there is a negative square wave on the plate of V115A. This negative square wave, when differentiated produces a negative pulse which has no effect on the *B*1-delay. The next positive pulse is fed to the *B*1-delay circuit and a negative pulse is fed to the *A*-delay circuit. Therefore, the start of the lower trace occurs at the same time as the start of the *B*1-delay.

The *B*1-delay is the length of time that V114B conducts. As in the *A*-delay circuit, 500-microsecond markers are used to lock the circuit. The coarse delay control setting determines how heavily V114B conducts and, therefore, determines how much bias is developed across the cathode resistor when V114B is conducting. The amount of cathode bias on V114A while it is cut off determines how much capacitor C162 has to discharge before this tube conducts, since the plate voltage for conduction varies with the grid bias.

The delay range of the *B*1-delay circuit is increased by increasing the time constant of C162, R163, and R162 as against that of C136, R132, and R133 in the *A*-delay circuit (figure 11-17). The output of the *B*1-delay circuit trips the *B*2-delay circuit.

### **B2-Delay Circuit**

The operation of the *B*2-delay circuit is the same as that of the *B*1-delay circuit. A schematic diagram of the *B*2-delay circuit is shown in figure 11-20. The fine delay control R138 determines the length of time that V112A conducts. The output is taken from the plate of V112B. The square wave is differentiated by capacitor C143 and resistor R146, when the right-hand section of V134 conducts. The differentiated negative pulse trips the pedestal



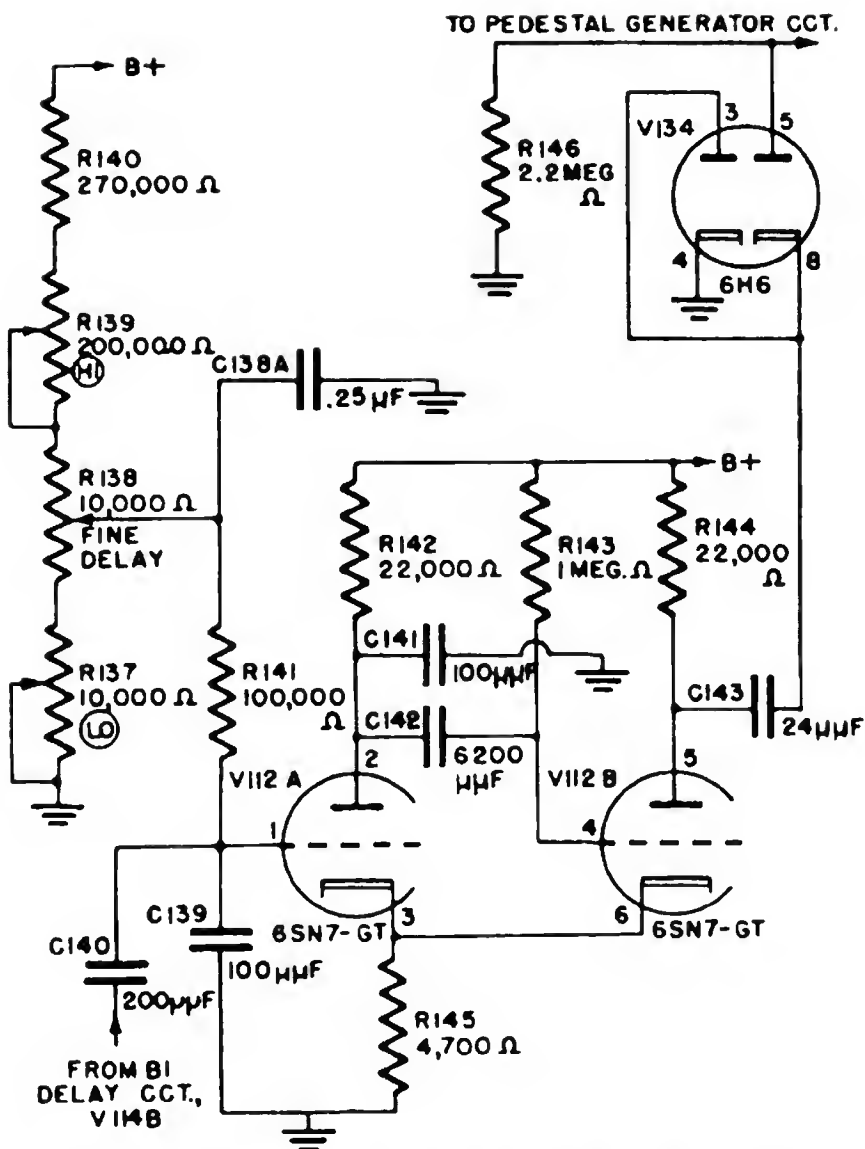


Figure 11-20.—Schematic diagram of the B2-delay circuit

generator. Resistor R146 is a common load for the outputs of both the A- and B2-delay circuits.

### Fast-Sweep Circuit

A schematic diagram of the fast-sweep circuit and the pedestal generator is shown in figure 11-21. The nega-

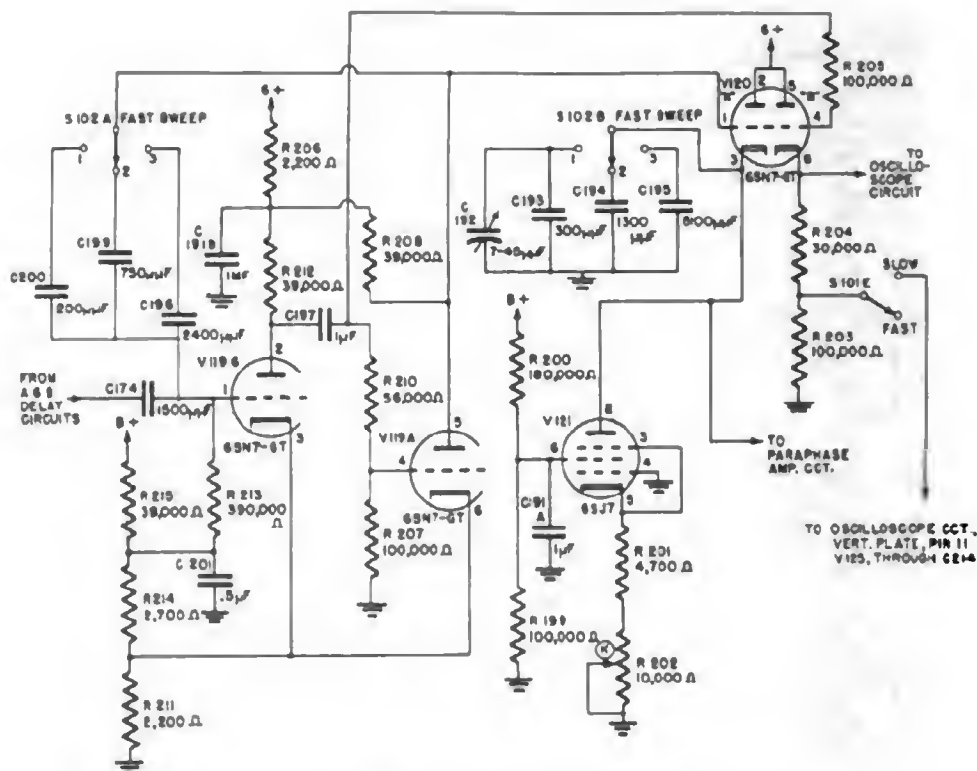


Figure 11-21.—Schematic diagram of the fast-sweep circuit.

tive pulses from both the A- and B2-delay circuits trigger pedestal generator V119. Tube V119B is normally conducting and V119A is normally cut off. When a negative pulse, from one of the delay circuits, is placed on the grid of V119B its plate current is suddenly reduced. There is a sharp increase in the plate voltage which causes the grid of V119A to go positive and V119A conducts. When V119A conducts, its plate voltage drops sharply. This drives the grid of V119B negative and cuts off this tube.

The length of time that V119B is cut off is determined by the time constant of resistor R213 and the capacitor selected by switch S102A. The positive voltage swing on the grid of V119A, when V119B is cut off, is placed on the grid of the cathode follower V120B. The plate current of V120B increases. This causes an increase in the volt-

age drop across cathode resistors R203 and R204. The voltage developed across the cathode resistors is placed on the intensity grid of the cathode-ray tube, when the sweep-speed switch is at FAST, in order to unblank the cathode-ray tube.

When the switch is in the SLOW position, the voltage developed across R203 is placed on the vertical deflection plates of the cathode-ray tube. This voltage is positive and deflects the trace upward producing a pedestal on the trace. Tubes V120A and V121 are part of the fast sweep circuit. Before a pulse from the delay circuits is placed on the grid of V119B, these tubes are conducting. The capacitor selected by switch S102B charges up to the plate voltage of V121. However, when V119A conducts, its plate voltage drops. This reduces the voltage on the grid of V120A to cutoff. The capacitor now supplies plate voltage for V121 and discharges through V121. The discharge of the capacitor has a saw-tooth waveform. The saw-tooth is coupled to the paraphase amplifier. The pedestal and sweep lengths are determined by the position of S102.

### **Paraphase Amplifier**

The paraphase amplifier is a phase-splitting circuit that converts the saw-tooth wave from either the fast- or slow-sweep circuit into a symmetrical push-pull saw-tooth wave. The push-pull saw-tooth wave is applied to the horizontal deflection plates of the cathode-ray tube. A schematic diagram of the paraphase amplifier is shown in figure 11-22. Without an input signal on its grids, V124 conducts. The outputs of the sweep circuits are negative saw-tooths.

The position of the sweep-speed switch S101B determines whether the output of the slow-sweep or the fast-sweep generator is applied to the grid of the paraphase amplifier. The negative saw-tooth on the cathode of this

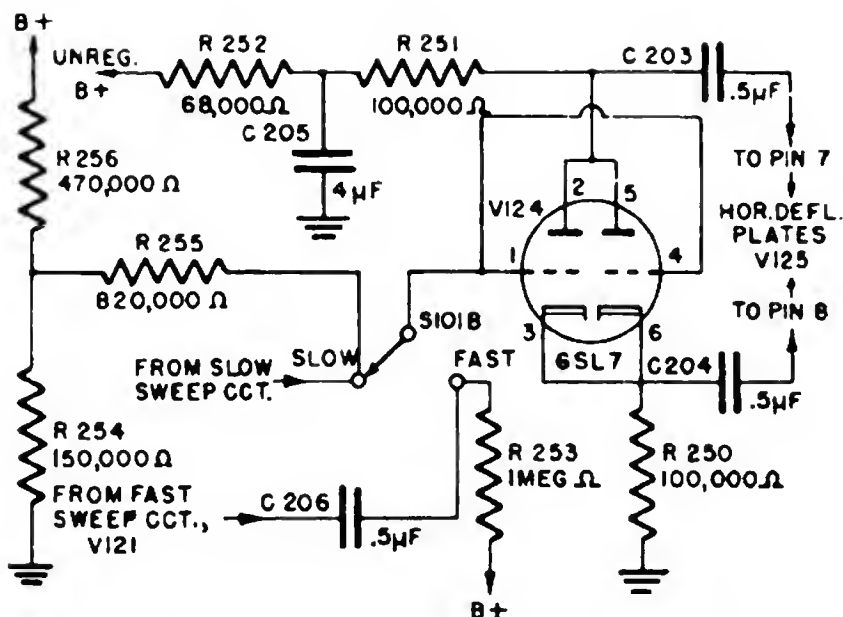


Figure 11-22.—Schematic diagram of the paraphase amplifier.

amplifier is coupled through capacitor C204 to one deflection plate while the positive saw-tooth in the plate circuit is coupled through capacitor C203 to the opposite deflection plate.

### Marker Mixer and Trace-Shift Mixer Circuit

Three inputs are fed to the marker mixer and trace-shift mixer circuit—50-microsecond markers, 500-microsecond markers, and a square wave. A schematic diagram of this circuit is shown in figure 11-23. Both triodes act as cathode followers. An output of the first counter (50-microsecond markers) and an output of the second counter (500-microsecond markers) are fed to the grid of V104B. These markers consist of both positive and negative pulses. Since the tube is almost cut off, because of the large cathode bias, only the positive pulses appear across the cathode resistors.

The coupling capacitors and resistors for the markers are chosen so that the 500-microsecond markers have

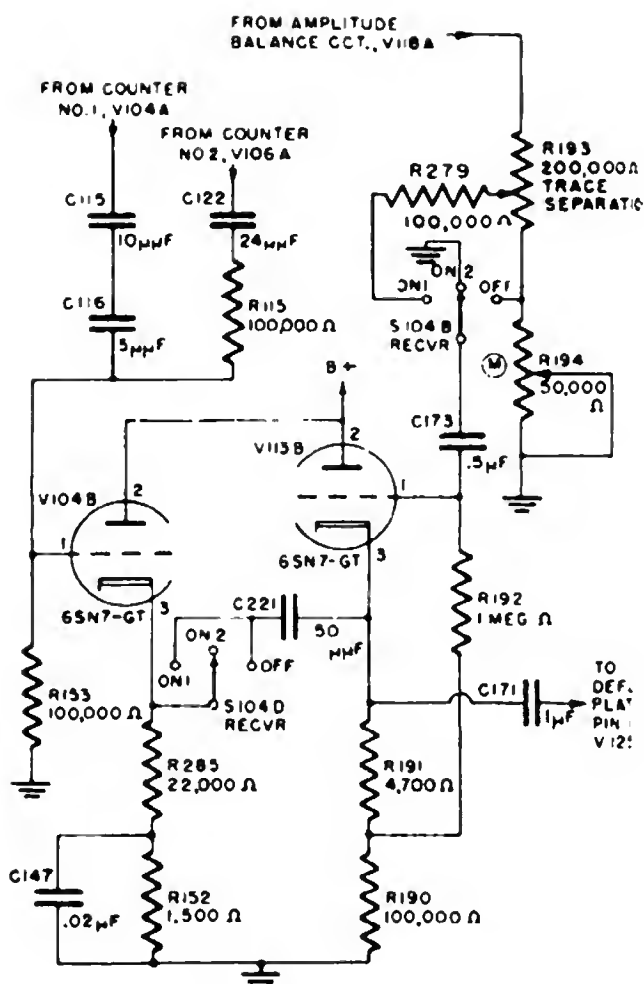


Figure 11-23.—Schematic diagram of the marker mixer and trace-shift mixer circuit.

four times the amplitude of the 50-microsecond markers. When the receiver switch is in the ON-2 position, section S104D removes the markers from the traces. This is done when the traces and the signal pulses are being superimposed. However, when the switch is in one of the other two positions, the markers appear across the cathode resistors of V113B in the trace-shift mixer.

The trace-shift mixer receives a square-wave input from the amplitude-balance circuit. The amplitude of the square wave is determined by the trace-separation con-

trol when S104B is in the ON-1 position. With S104B in the ON-2 position, the trace separation is removed. In the OFF position, a square wave of small amplitude is taken from R194 and applied to the grid of V113B to give a small trace separation. The bias on V113B is developed across cathode resistors R190 and R191. The grid is returned to the center of these two resistors which is positive with respect to ground.

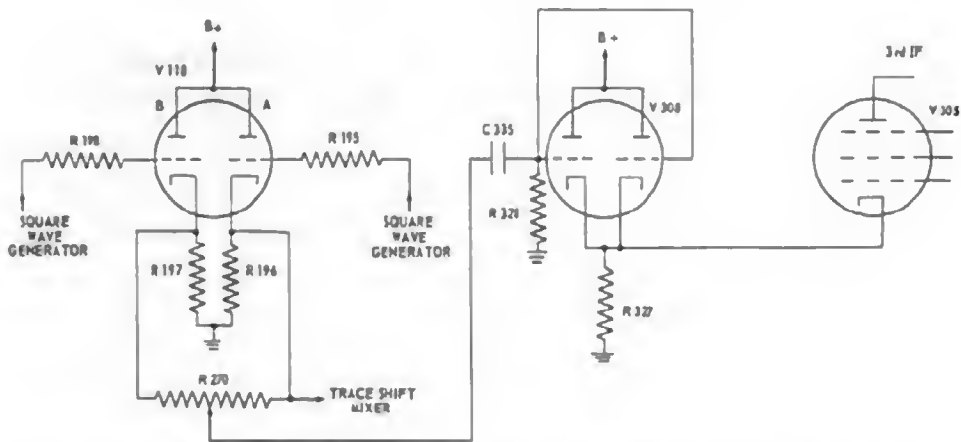
The purpose of connecting the grid at this point is to provide a small amount of negative feedback to reduce distortion and yet to keep the output at a moderately high impedance. The square wave coupled to the grid appears in the cathode circuit. The markers are superimposed on the square wave and coupled to the lower vertical deflection plate through capacitor C171.

### **Amplitude-Balance Circuit**

The amplitude-balance circuit provides different amounts of receiver gain during the upper and lower traces. Suppose that the loran receiver is located closer to one of the loran stations than to the other. The signal from the closer station usually will be greater in amplitude. The amplitude of the two signals cannot be equalized by the gain control because this control affects both signals.

With the amplitude-balance control the gain of the third i-f amplifier in the receiver may be decreased either during the upper trace or the lower trace. Since the signal from the master station is on the upper trace and the signal from the slave station is on the lower trace, the two signals can be made to have the same amplitude. The amplitude-balance control is adjusted to reduce the amplitude of the stronger signal until it is equal to that of the weaker signal. The gain control is adjusted so that the signals have reasonable amplitude.

A schematic diagram of the amplitude-balance circuit is



**Figure 11-24.**—Schematic diagram of the amplitude-balance circuit.

shown in figure 11-24. The grids of V118 are driven with a push-pull square wave from the square-wave generator. Potentiometer R270 is bridged across the cathode resistors. Grounding the junction of the cathode resistors effectively grounds the center of the potentiometer. If the arm of the potentiometer is moved from the center toward either end, a square wave appears on the arm and is coupled to the cathode follower, V308, in the receiver. The amplitude of this square wave depends on how far the arm is moved from the center. The direction in which the arm is moved away from center determines which of the two loran signals has its amplitude reduced.

When the arm of R270 is in its mid position no square wave is applied to V308 and its conduction is limited only by the cathode bias resulting from the space current of V305 and V308. If the arm of R270 is moved off-center, a square wave is applied to the grids of V308 causing increased conduction during one sweep and decreased conduction during the other sweep. Since the cathode resistor R327 is common to both V308 and V305 this causes the gain of V305 to be decreased and increased accordingly. Moving the arm of R270 to the other side of center causes the decrease and increase of gain to be interchanged.

## Oscilloscope Circuit

A schematic diagram of the oscilloscope circuit is shown in figure 11-25. The intensity control varies the negative bias placed on the grid of the cathode-ray tube. The horizontal and vertical centering controls are used to vary the average d-c potential between the deflection plates. Each centering control is made up of two potentiometers ganged together. As the control is moved in one direction, the voltage at the arm of one potentiometer increases while the voltage at the other arm decreases. When the control is turned in the opposite direction, the situation is reversed.

A change in the magnitude of the effective horizontal centering voltage is encountered in switching from the fast sweep to the slow sweep. This is due to the effect of the impedance of coupling capacitors C203 and C204 (figure 11-22) on the average voltage between the horizontal deflection plates. The change is canceled by shorting resistors R238 and R241 by the sweep-speed switch during the slow sweep.

Whenever the fast sweep is used, it is necessary that the electron beam be cut off except for the period of each sweep. Otherwise brilliant spots would appear at the left-hand edge of each sweep because of the relatively long time between sweeps. When the sweep-speed switch is set at FAST, a positive pulse of voltage appears on the grid of the cathode-ray tube during the forward part of the sweep. This positive pulse coupled through capacitors C202 and C218 causes diode connected V135 to conduct, thus charging these capacitors. The resistance of V135, while conducting, is very small compared with that of resistor R249. After the end of the positive pulse capacitors C202 and C218 discharge through resistor R249. The voltage developed across R249 during the discharge of the capacitors blanks the cathode-ray tube until the next positive pulse.



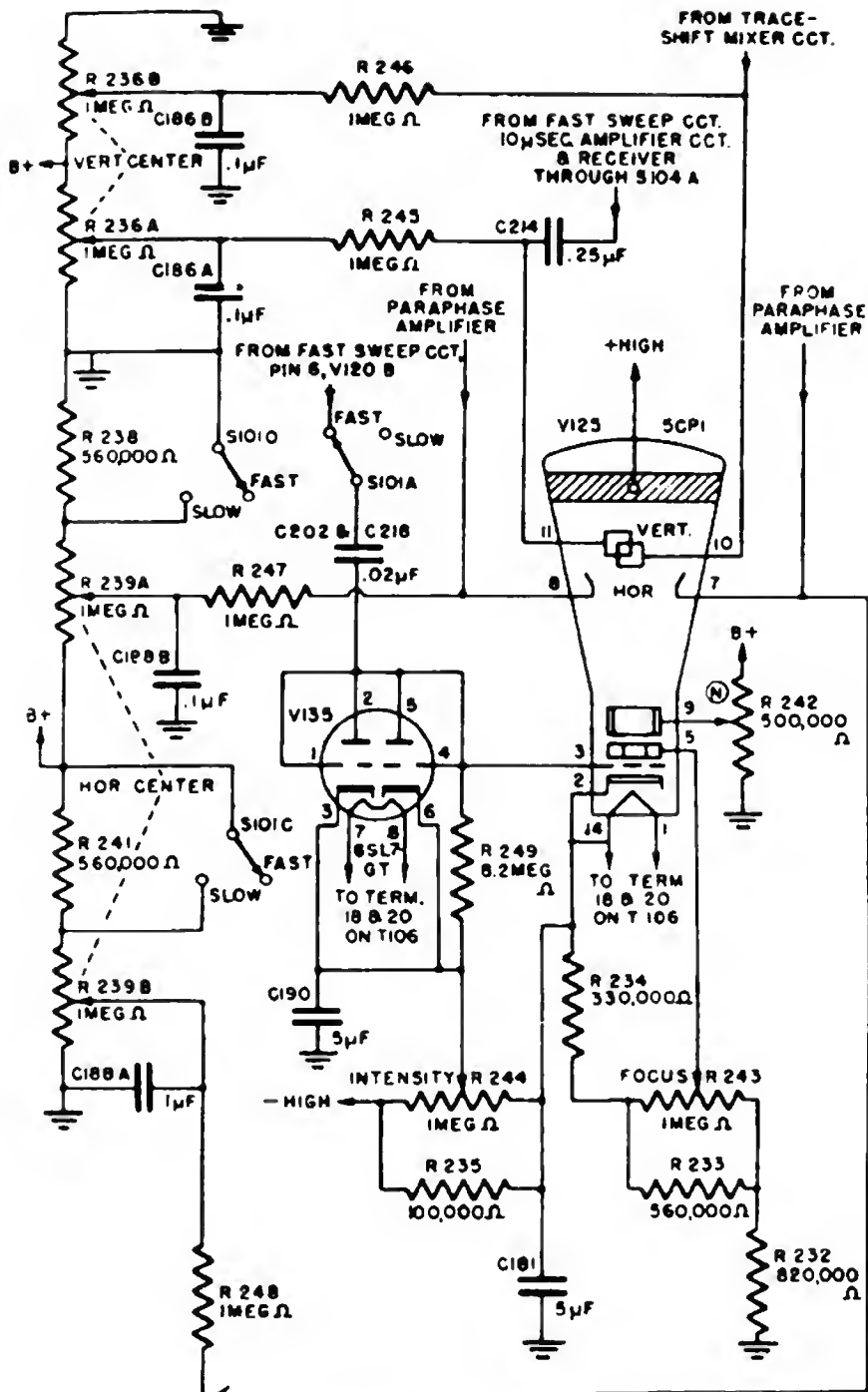


Figure 11-25.—Schematic diagram of the oscilloscope circuit.

## Power Supply

One transformer supplies all the a-c voltages necessary for the operation of the indicator. A schematic diagram of the indicator power supply is shown in figure 11-26,A. The winding between terminal 21 and terminal 24 supplies about 1000 volts to V126 and V127. V126 and its associated filter supply a high positive voltage for the intensifier anode of the cathode-ray tube. V127 and its filter supply a negative voltage to the grid and cathode of the cathode-ray tube. The winding between terminals 22 and 17 supplies a-c voltage to the full-wave rectifier V128.

A schematic diagram of the voltage regulator is shown in figure 11-26,B. This is an electronic voltage regulator and provides better regulation than a VR tube alone. The parallel combination of V129 and V130 is in series with the load on the B+ regulated bus. Potentiometer R231 is used to adjust the positive voltage between the grid of V131 and ground. This grid bias is used to set the regulated output voltage to the desired value.

Suppose the voltage across resistor R221 increases because of a line voltage increase. This voltage is distributed across the parallel triodes and resistor R230 and potentiometer R231 in series. The increased voltage tends to increase the voltage between the regulated bus and ground. This voltage is distributed across R230 and R231. The positive voltage between the grid and ground of the control tube increases and so does its plate current. However, the cathode bias is held constant by VR150. Therefore the net grid bias decreases and the plate voltage decreases as plate current increases. The plate voltage on the control tube V131 is used also as part of the bias on the two triodes. When the positive voltage between grid and ground is reduced (which is equivalent to changing the grid bias in a negative direction), the effective resistance of the triodes increases and more voltage is dropped across these tubes, counteracting the rise in



voltage at the regulated bus. When the load voltage decreases, the opposite condition occurs. The plate voltage of the control tube increases and there is less voltage drop across the triodes.

## QUIZ

1. How are the signals from a pair of loran stations displayed on the DAS-4 loran-indicator?
2. What is the purpose of the wave traps in the grid circuit of the r-f amplifier of the DAS-4 receiver?
3. What type of oscillator is used as a local oscillator in the DAS-4 receiver?
4. The output of the video amplifier in the DAS-4 receiver is coupled to what components?
5. What is the purpose of the indicator unit of the DAS-4?
6. What precaution must be taken after superimposing and matching the two pulses in the indicator screen?
7. How are pulses, at twice the PRR of corresponding pairs of loran stations, obtained from the output of the standard frequency generator?
8. What is the purpose of the drift control in the standard frequency generator circuit?
9. How is a square wave obtained from the squaring amplifier?
10. For normal operation five input pulses to the first counter are required for one output pulse. What effect would adjusting R109 (figure 11-12) for too much bias have on the operation of the first counter?
11. What circuits are tripped by the output of the fourth counter?
12. What type of circuit is used as the square-wave generator?
13. What determines the positions of the pedestals on their respective traces?
14. What is the difference between the delay introduced by the *A*-delay circuit and the delay introduced by the *B*-delay circuit?
15. Where is the push-pull saw-tooth output of the paraphase amplifier applied?

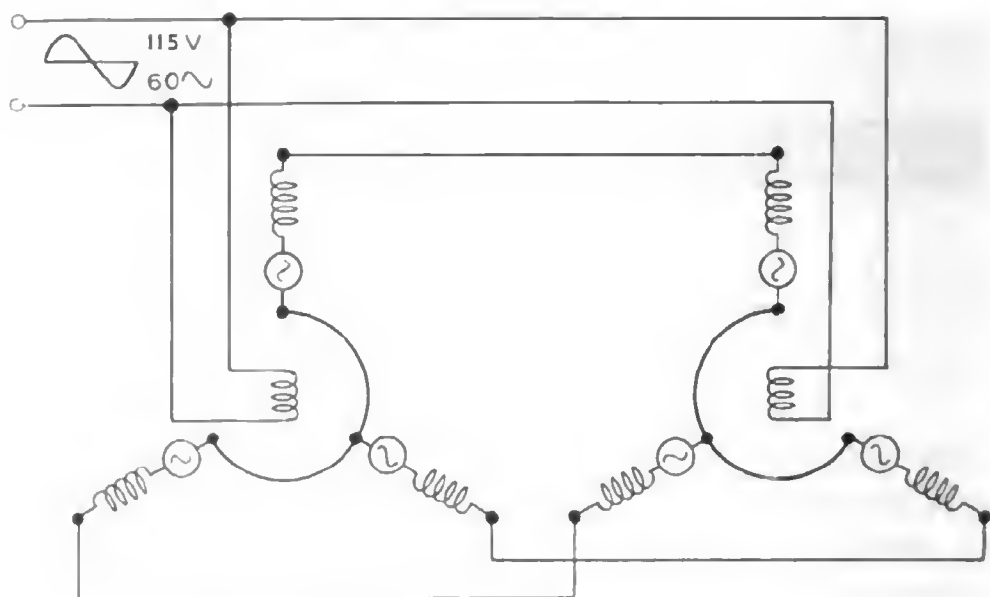
16. In figure 11-23, what is the purpose of returning the grid of V113B to the junction of R190 and R191?
17. If the signals from the slave and master stations are not the same amplitude why can they not be equalized by setting the gain control of the receiver?
18. In figure 11-24, what determines the amplitude of the square wave on the arm of potentiometer R270?
19. In figure 11-26, B, how is the regulated output voltage changed?
20. If the voltage on the regulated bus in figure 11-26, B, increases what happens to the amount of voltage dropped across the triodes?



## SYNCHROS

The Navy term “synchro” is applied to small self-synchronous a-c machines used extensively in fire control, I.C. systems, and other electronic installations for the purpose of transmitting angular motion from one location to another. The simplest synchro transmission system consists of a self-synchronous generator called a **TRANSMITTER** (formerly called “synchro generator”) and a self-synchronous motor called a **RECEIVER** (formerly called “synchro motor”) connected as shown in figure 12-1,A. The transmitter and receiver are called self-synchronous because, when properly connected and energized from a common source, the receiver rotor turns in synchronism with and through the same angle as the transmitter rotor.

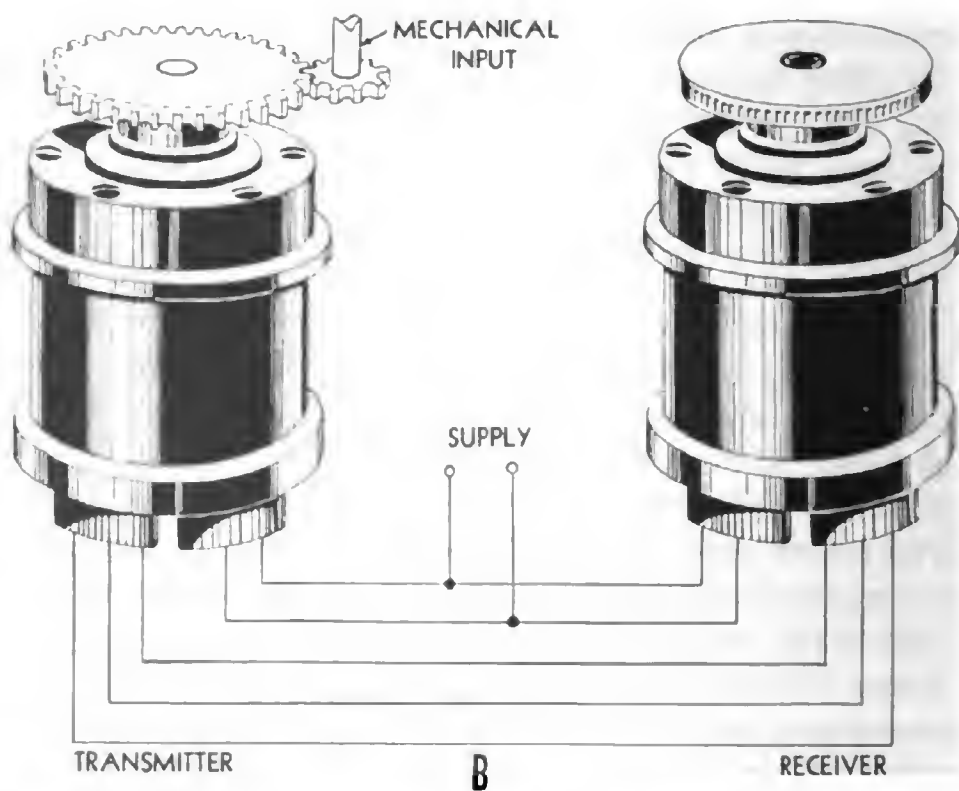
The synchro transmitter and receiver (figure 12-1,B) are similar to miniature 2-pole alternators except that the rotors are supplied with alternating current instead of direct current. The operation of both transmitter and receiver resemble that of a single-phase transformer. The rotors are energized by a single-phase voltage from a common source and constitute the primaries. The wye-connected stator windings comprise the secondaries. When the transmitter and receiver rotors are in correspondence, the stator voltages across corresponding stator terminals in the two units are equal in magnitude and



TRANSMITTER

A

RECEIVER



TRANSMITTER

B

RECEIVER

Figure 12-1.—Synchro transmission system. A, Schematic; B, outside view.



opposite in phase. Thus the current is zero in the connecting lines between the stators of the two units.

If the rotors are not in correspondence, the voltages induced by transformer action in the transmitter stator windings are unbalanced with respect to those induced in the same manner in the receiver stator windings. The resulting currents between the two stators establish a torque in the receiver rotor which turns this rotor into correspondence with the transmitter rotor. Thus to transmit a signal, the transmitter rotor is turned through a given angle and the receiver rotor follows almost simultaneously through the same angle.

### CONSTRUCTION OF SYNCHRO TRANSMITTERS AND RECEIVERS

The stators of a receiver and a transmitter are electrically and mechanically identical. A stator is shown in



Figure 12-2.—Stator of a synchro transmitter or receiver.

figure 12-2. The stator consists of a fabricated steel cylindrical shell containing slotted transformer-steel laminations which house an armature winding similar to that of an ordinary a-c motor. The windings in the stator slots consist of three groups of coils the axes of which are 120 mechanical degrees apart. The three groups of coils are wye-connected to form a 2-pole 3-circuit distributed winding. The three free ends of the winding are attached to leads that are brought out from the rear end cap. These leads are marked S1, S2, and S3.

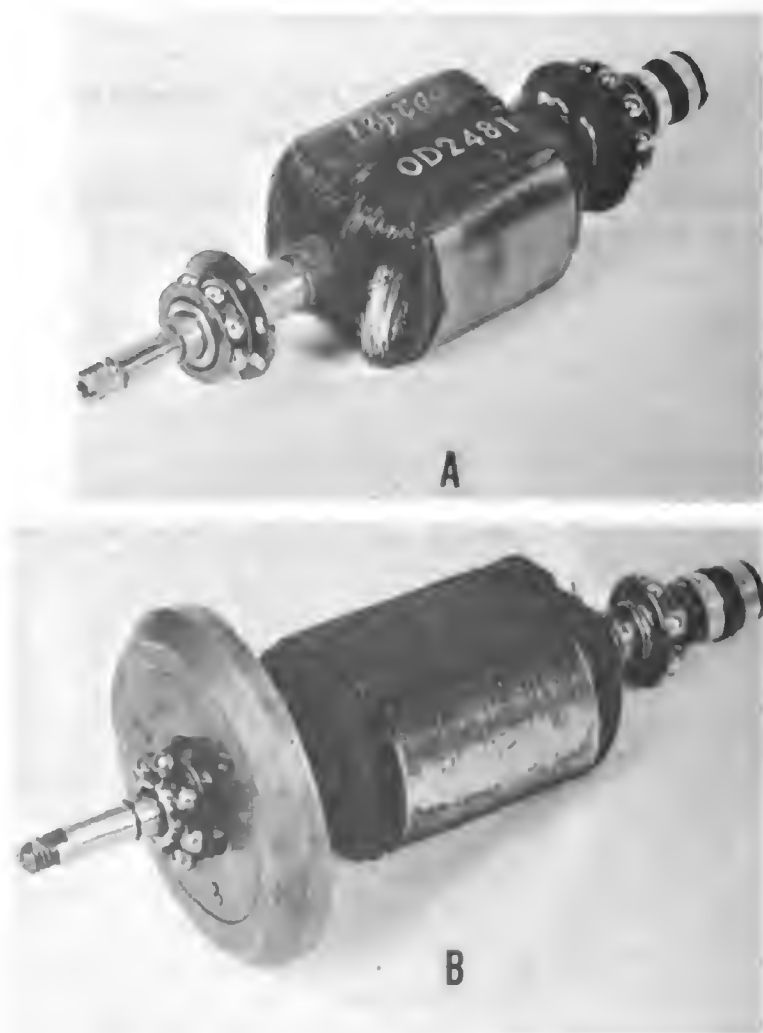


Figure 12-3.—Synchro rotors. A, Transmitter, B, receiver.

The rotors of the transmitter (figure 12-3,A) and of the receiver (figure 12-3,B) are electrically identical. Each rotor consists of a laminated-steel core secured to the shaft by a collar. The rotor has two salient poles and a concentrated single-phase winding. Each rotor winding comprises a single coil, the axis of which coincides with that of the salient poles. The two free ends of the winding are connected to two insulated slip rings mounted on the shaft. The leads are brought out from the rear end cap and are marked R1 and R2. Each rotor coil is energized through slip rings from a common single-phase 115-volt source.

The transmitter and receiver rotors are mechanically similar except that the receiver rotor has an INERTIA DAMPER (figure 12-3,B). This damper consists of a metal flywheel mounted on ball bearings. It is provided with a keyed bushing and a friction disk assembly. The damper applies a braking effect to the receiver rotor to prevent it from oscillating or spinning.

The end caps which support the rotor bearings are flange-fitted to the shell and secured to the stator housing with machine screws. The brush assembly is mounted on an insulator outside the rear end cap. The rear end cap contains a spring in the rear of the bearing race for



**Figure 12-4.—Exploded view of a synchro transmitter.**

automatic bearing adjustment. Figure 12-4 is an exploded view of a synchro transmitter.

## OPERATION OF SYNCHRO TRANSMITTERS AND RECEIVERS

The voltages induced in the three stator windings of a synchro differ from those induced in the conventional a-c generator or motor in two respects: (1) In the synchro the three voltages are induced by transformer action while in the a-c generator or motor they are induced by rotation; and (2) in the synchro the voltages are always either in phase or  $180^\circ$  out of phase, while in the a-c generator or motor they are  $120$  electrical degrees out of phase.

The turns ratio between the rotor and stator of a synchro is standardized. When single-phase 115-volt power is applied to the rotor, the highest rms voltage that may be induced in any one stator coil is 52 volts. A maximum of 52 volts (rms) is induced in coil S2 of the synchro shown in figure 12-5 because the axes of the rotor and coil S2 are in alignment and the coupling is a maximum. (In figure 12-5 and all subsequent figures, the voltage directions are indicated by arrows for the instant of time shown by the dot on the sine wave of the rotor supply voltage.) The a-c generator symbol inserted in series with each of the synchro phases indicates the presence of a mutually induced voltage.

The voltage induced in each of coils S1 and S3 is 0.5 of the highest rms voltage, or 26 volts, because the rotor is displaced  $60^\circ$  from coils S1 and S3 and the coupling is proportional to  $\cos 60^\circ$ . Since the flux linking coil S2 is opposite in direction to the flux linking coils S1 and S3, the direction of the emf induced in coil S2 is opposite to the direction of the emf induced in coils S1 and S3. The 52 volts of coil S2 add to the 26 volts of coils S1 and S3.

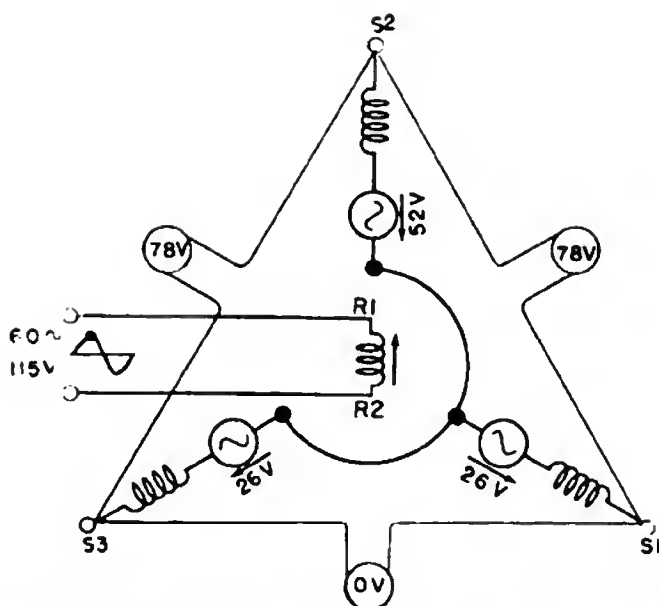


Figure 12-5.—Voltage distribution of a synchro transmitter or receiver. (Electrical zero.)

Therefore, the voltage between S1 and S2 and also between S2 and S3 is 78 volts. The voltage between coils S1 and S3 is zero because the S1 and S3 coil voltages,

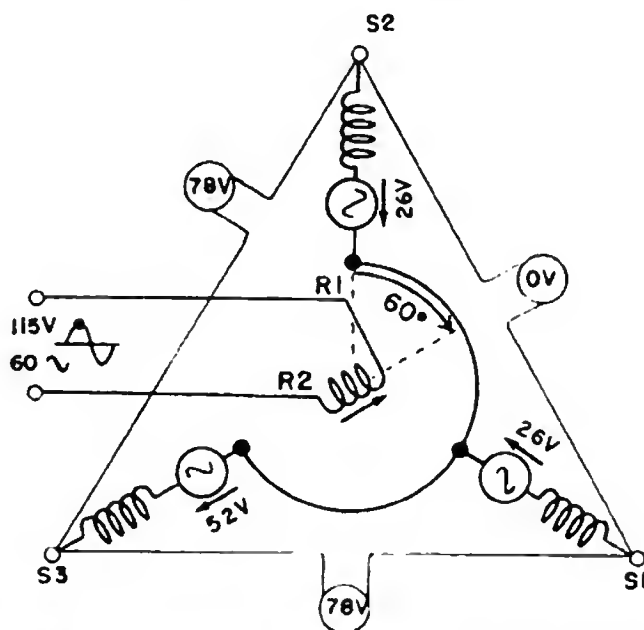


Figure 12-6.—Voltage distribution with the rotor turned 60°.

being equal in magnitude and opposite in phase, cancel each other.

When the rotor is turned  $60^\circ$  clockwise and its axis is lined up with the axis of coil S3 (figure 12-6), the voltage in coil S3 is 52 volts whereas the voltages in coils S1 and S2 are each 26 volts. The phase of the voltage induced in S1 is reversed with respect to that in S1 in figure 12-5 because the direction of the flux through it is reversed at the corresponding instant in the cycle. As the rotor turns from  $0^\circ$  to  $30^\circ$  to  $60^\circ$ , the rms voltage in

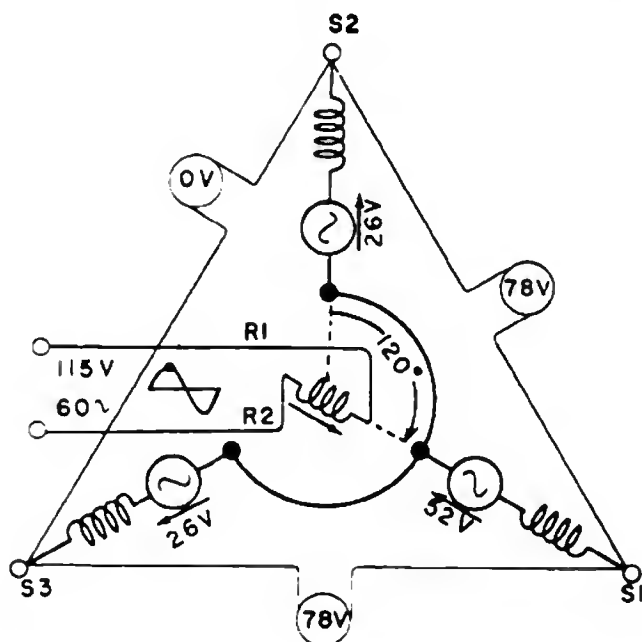


Figure 12-7.—Voltage distribution with the rotor turned  $120^\circ$ .

coil S1 decreases from 26 volts to zero, reverses, and increases to 26 volts with opposite polarity.

When the rotor is turned another  $60^\circ$  ( $120^\circ$  from its original position) its axis is in alignment with the axis of coil S1 (figure 12-7). The S1 coil voltage is now 52 volts and the S2 and S3 coil voltages are each 26 volts.

The voltage relations just considered apply equally to synchro transmitters and synchro receivers. This is true

because a transmitter and receiver are electrically identical and their rotors are energized from the same source. The rotor angle is measured clockwise from the axis of coil S2 to the axis of the R1 pole. The axis of coil S2 is the standard reference and is called the ELECTRICAL ZERO POSITION when the rotor axis is aligned with it as shown in figure 12-5.

## SYNCHRO TRANSMISSION SYSTEM

A simple synchro transmission system consists of a transmitter connected to a receiver. The R1 transmitter and receiver leads are connected to one side of the a-c. supply line. The R2 transmitter and receiver leads are connected to the other side of the supply line. Thus, each rotor is excited from the same supply. The stator leads S1, S2, and S3 of the transmitter are connected to corresponding stator leads in the receiver. Thus the voltage in each of the transmitter coils is opposite in phase to the voltage in each of the corresponding receiver coils.

When both rotors are turned through the same angle from electrical zero, they are in correspondence and the voltages induced in each pair of corresponding transmitter-receiver stator coils are equal. Hence, there is zero resultant voltage and zero current in the stator coils. If the two rotors are not in correspondence, the voltages across corresponding stator coils are not equal. These unequal voltages cause currents to flow in the lines and coils producing stator flux fields which exert torques on the rotors. These currents are limited by the impedance of the coils and lines and the magnitude of the unbalanced voltage.

The reaction torque does not turn the transmitter rotor since this rotor always is rotated and held in position mechanically. However, the receiver rotor, being free to rotate, turns into correspondence with the transmitter





rotor. When a synchro system is in correspondence (figure 12-8), the stator voltages are equal and opposite, no current flows, no torque is exerted, and the rotors remain stationary.

The angle through which a transmitter rotor is turned mechanically is called a **SIGNAL**. For analysis, the transmitter rotor is turned  $60^\circ$  out of correspondence with the receiver rotor in figure 12-9. As the transmitter rotor is turned, the rms voltage of transmitter coil S2 decreases, coil S1 voltage reverses phase, and the rms voltage of coil S3 increases. Immediately current flows between the transmitter stator and the receiver stator in the direction of the greater induced voltage. The unbalanced voltage is absorbed in the line drop and in the internal impedance of the windings.

Assume the stator currents in the synchro receiver (at

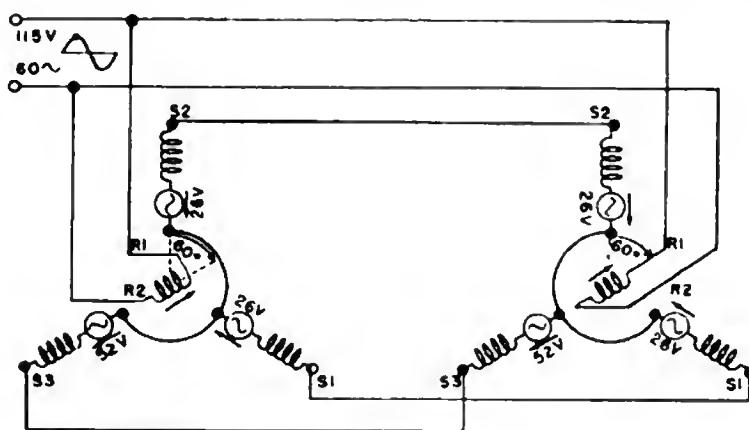


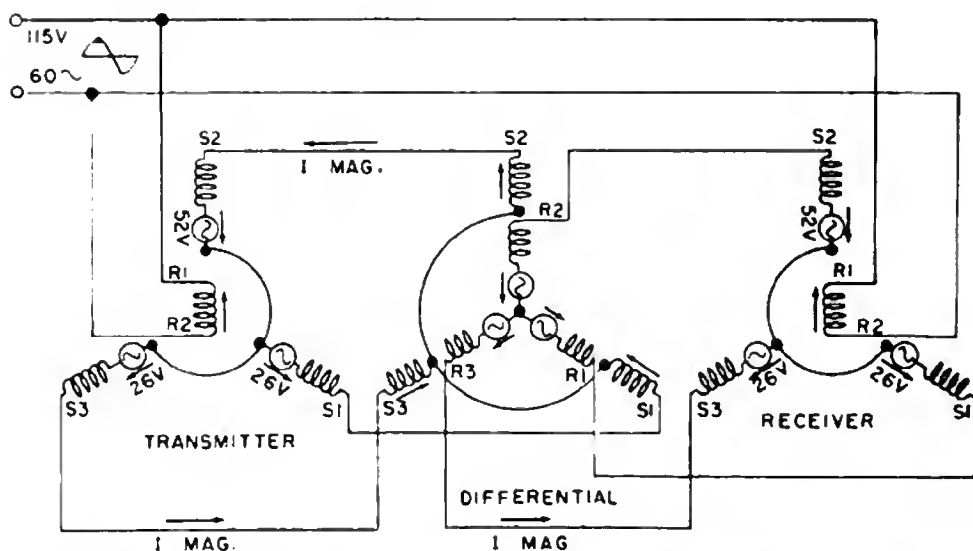
Figure 12-10.—Simple synchro system, with rotors in correspondence.

the time indicated by the dot on the sine curve) to establish a north pole in S2, a south pole in S1, and a north pole in S3. This polarity produces a torque on the receiver rotor which causes it to turn. The receiver rotor turns until the stator voltages in the transmitter and receiver are again equal. Then the two rotors are in correspondence as shown in figure 12-10.

## DIFFERENTIAL TRANSMITTERS AND RECEIVERS

The synchro differential transmitter and the differential receiver are electrically identical. The only mechanical difference is that the differential receiver is equipped with an inertia damper to prevent oscillation or spinning of the rotor.

The stator of a differential transmitter or receiver is similar to the stator of a synchro transmitter or receiver. The three wye-connected windings are marked S1, S2, and S3.



**Figure 12-11.—Synchro system using a differential transmitter.**

The rotor of a differential transmitter or receiver is similar to the wound armature of an induction motor in that it consists of three wye-connected windings. The free ends are connected to slip rings mounted on the shaft, and the leads are marked R1, R2, and R3.

A synchro system containing a differential transmitter is shown in figure 12-11. Both the differential transmitter and the differential receiver act as a 1-to-1 transformer. The stator in each must always be connected as the pri-

mary, since the rotor contains a greater number of turns of wire to compensate for losses. The differential rotor is not connected to the rotor supply of the synchro transmitter and receiver. The arrows on the stator coils of the synchro differential transmitter indicate the direction of the magnetizing current at the instant indicated by the dot on the sine curve. The arrows on the synchro differential rotor, the transmitter stator, and receiver stator, indicate the direction of induced voltage for this instant in the cycle.

The magnetizing current ( $I_{mag}$ ) sets up the magnetic field in the differential transmitter. In figure 12-11 a signal from the differential transmitter subtracts from the signal from the synchro transmitter to supply a signal to the synchro receiver equal to their difference. For example, if the transmitter rotor is turned clockwise  $60^\circ$ , its axis in this position coincides with that of coil S3. The rms voltage in coil S3 becomes maximum and that in coils S2 and S1 half of maximum. These voltages are applied to the stator of the synchro differential transmitter. The axis of the synchro differential stator field follows the transmitter rotor through  $60^\circ$  and aligns itself with the axis of coil S3.

The synchro differential rotor is assumed held in the electrical zero position. Thus, as the differential stator field axis turns into alignment with the axis of coil S3, the field axis also coincides with the axis of differential rotor coil R3. The synchro differential transmitter acts as a 1-to-1 transformer and transmits the signal to the synchro receiver. At the same time the axis of the receiver stator field turns clockwise  $60^\circ$  into alignment with the axis of receiver coil S3. The synchro receiver rotor simultaneously turns clockwise  $60^\circ$  thereby maintaining alignment of its axis with that of the receiver stator field. The receiver rotor turns in step with the

transmitter rotor when the differential transmitter signal is  $0^\circ$  ( $60^\circ - 0^\circ = 60^\circ$ ).

If the synchro transmitter rotor is turned clockwise  $60^\circ$ , the synchro differential transmitter stator field axis turns clockwise  $60^\circ$  into alinement with the axis of differential stator coil S3. If, at the same time, the synchro differential rotor is turned clockwise  $60^\circ$ , the axis of differential rotor coil R2 will come into alinement with the axis of the differential stator field (itself in alinement with the axis of differential stator coil S3). The synchro receiver remains on electrical zero ( $60^\circ - 60^\circ = 0^\circ$ ) because the axis of differential rotor coil R2 coincides with that of the differential stator field which was the relationship existing in the synchro differential when the transmitter and differential were both on electrical zero.

Another example arises when the rotor of the synchro transmitter is turned  $30^\circ$  and the rotor of the differential transmitter is turned  $60^\circ$ . The output is  $30^\circ - 60^\circ = -30^\circ$ , or  $330^\circ$ . The rotor of the synchro receiver turns to a position corresponding to  $330^\circ$  measured clockwise from electrical zero.

The system also can be connected so that the two signals add. This can be done by reversing the S1 and S3 connections from the synchro transmitter to the differential transmitter and also reversing the R1 and R3 connections from the differential transmitter to the synchro receiver. When the differential transmitter is used in the manner described, it receives an electrical input from the synchro transmitter and a mechanical input from a crank or other device which turns the differential rotor and produces an electrical output to the synchro receiver which is the sum of these two inputs.

The differential receiver is electrically connected in the same manner as a differential transmitter. However, instead of producing an electrical output it produces a mechanical output. The differential receiver is connected

to two synchro transmitters. It receives two electrical inputs from these transmitters and produces a mechanical output (rotation of the differential receiver rotor).

## CONTROL TRANSFORMERS

A control transformer is used extensively to compare the angular positions of two devices in a servo system. It is similar in appearance to the other synchros. However, the windings are different. The stator and rotor are wound with a large number of turns of fine wire and hence they have a higher impedance than other synchros.

The stator has a three-circuit wye-connected winding. The free ends are brought out through the housing and are marked S1, S2, and S3. The rotor is similar in appearance to the rotor of a synchro differential in that it has no salient poles but its winding forms a single coil. The two rotor leads are connected to slip rings mounted on the rotor shaft. The rotor leads are marked R1 and R2. The rotor is not connected to an a-c supply but receives its voltage by transformer action from the stator.

In a control transformer the excitation voltage is connected to the stator instead of the rotor as is the case in synchro transmitters and receivers. Since the stator coils have a high impedance, little current flows through them. Also, there is no appreciable current flowing in the rotor. The rotor does not tend to turn to any particular position when voltage is applied to the stator since the control transformer produces negligible torque. The shaft is always turned mechanically and does not require an inertia damper.

When the control transformer is in the electrical zero position, its rotor axis is mechanically displaced  $90^\circ$  from the zero position of a synchro transmitter or receiver. Figure 12-12 shows a control transformer connected elec-

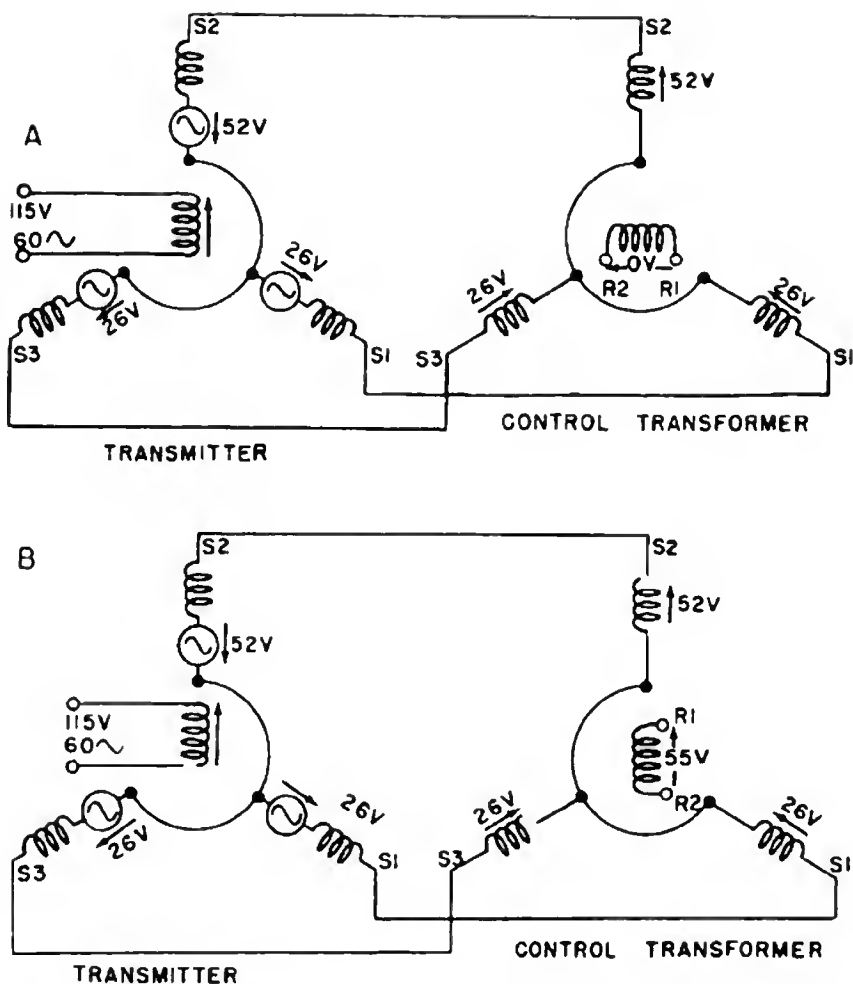


Figure 12-12.—Operation of a control transformer. A, Electrical zero, B, rotor at 90°.

trically to a synchro transmitter. With both at electrical zero (figure 12-12,A) no voltage is induced in the rotor of the control transformer because the axis of the rotor coil is 90° out of alignment with the axis of the stator field.

In figure 12-12,B, the rotor has been turned 90° counterclockwise (270°) so that maximum coupling exists between the rotor and the stator field. The 55 volts appearing across the rotor is the maximum rms voltage that can be induced into the rotor. As the rotor is turned

to this position, the voltage gradually increases to 55 volts rms. Turning the rotor toward  $180^\circ$  causes the voltage to decrease, until at  $180^\circ$  the voltage across the rotor is again zero.

If the synchros are connected as shown in figure 12-12, a counterclockwise rotation (as viewed from the shaft end) of the control transformer rotor causes a voltage to be induced into the rotor which is in phase with the voltage on the rotor of the transmitter. The rotor of the control transformer is shown at its  $180^\circ$  position in figure 12-13,A. Again no voltage is induced in the rotor. Rotating the rotor to  $90^\circ$  ( $270^\circ$  counterclockwise) again

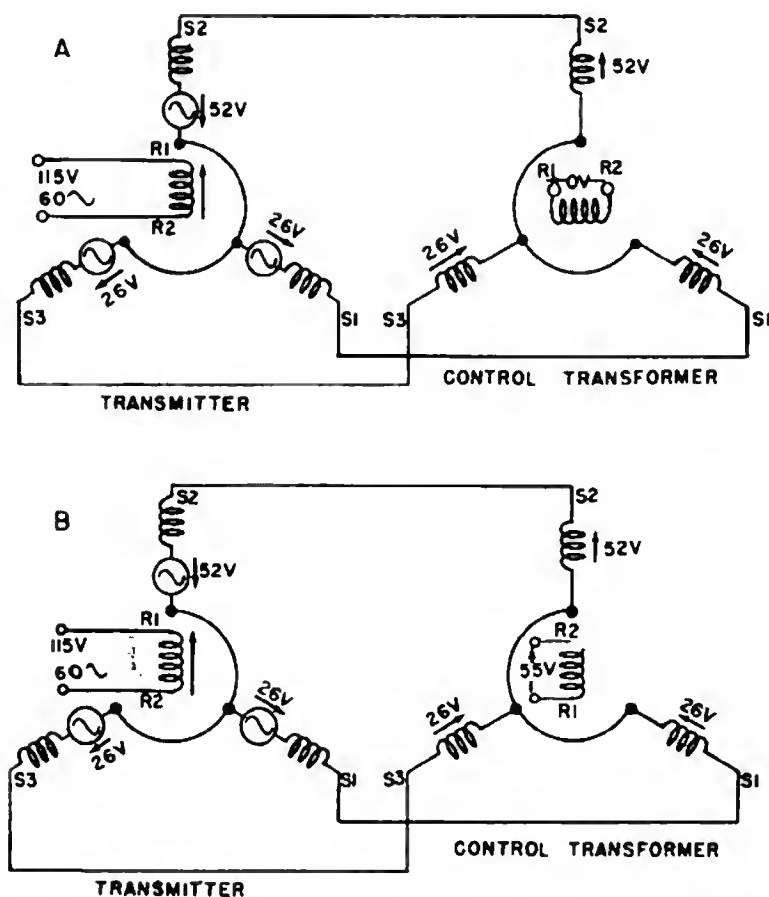


Figure 12-13.—Operation of the control transformer. A, Rotor at  $180^\circ$ ; B, rotor at  $270^\circ$  counterclockwise.

causes maximum voltage to be induced in the rotor. However, in this position the voltage induced in the control transformer rotor is  $180^\circ$  out of phase with the voltage across the rotor of the transmitter (figure 12-13,B).

When the rotor of the control transformer is in correspondence with the rotor of the synchro transmitter, the output of the control transformer is zero. If the shaft of the transmitter is turned, an error signal will appear across the rotor of the control transformer. The amplitude of this error signal depends on the amount the transmitter shaft was turned while the phase depends on the direction the transmitter shaft was turned.

## SYNCHRO CAPACITORS

Synchro capacitors are used to reduce the load current on a synchro transmitter. A synchro capacitor of the proper size is connected to the stator leads of every differential and control transformer in a synchro system. This reduces the current drawn from the transmitter by improving the power factor of the circuits. The stator coils of a control transformer place an inductive load across the stator of a synchro transmitter.

The excitation current flowing in the stator coils may be considered as a combination of two currents—the loss current which is in phase with the stator voltage of the transmitter and the magnetizing current which lags the stator voltage by  $90^\circ$ . The loss current supplies the losses of the control transformer stator and its core. The magnetizing current produces the magnetic field around the stator coils of the control transformer. The loss current is small compared to the magnetizing current. The capacitors supply the magnetizing current and thus reduce the excitation current supplied by the synchro transmitter by an amount which cannot exceed the magnetizing current.

Since the control transformer is usually located at some



point remote from the synchro transmitter, the interconnecting leads are long. If the excitation current is reduced, the losses in the interconnecting leads are reduced and the accuracy of the system is increased.

The connection of a synchro capacitor to a control transformer is shown in figure 12-14. The synchro capacitor is located as close as possible to the control transformer. The capacitor current is reactive and  $180^\circ$  out of phase with the magnetizing current. The two cur-

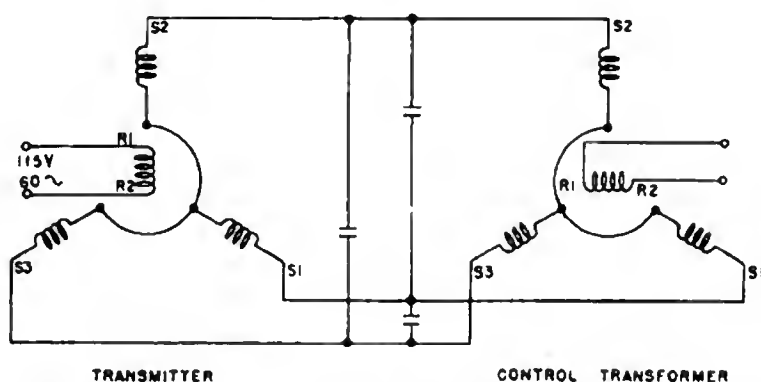


Figure 12-14.—Connection of a synchro capacitor to a control transformer.

rents cancel each other. The result is that the power factor is increased toward unity and the magnetizing current flowing through the interconnecting leads is almost eliminated.

A synchro capacitor is made up of three individual capacitors. These capacitors have a 10-percent tolerance but they are matched so that their capacitances are alike within 1 percent. The exact capacitance is not critical but, if the capacitors are not matched, the current flowing in the stator leads is unbalanced and the accuracy of the synchro system is reduced. A synchro capacitor is not used in a synchro system containing only transmitters

and receivers. The reason for this is the fact that there is no current flowing in the stator leads when the transmitters and receivers are in correspondence.

## ZEROING SYNCHROS

A synchro receiver may be zeroed by disconnecting the stator leads and reconnecting them to the rotor leads as follows. Connect S2 to R1 and connect S1 and S3 to R2. Apply 110 volts alternating current to R1 and R2. The receiver will turn definitely to 0°. If the receiver shaft has a dial on it, loosen the dial and turn it to zero. A receiver should not remain connected in this way very long because 115 volts instead of the normal 78 volts is connected between S1 and S3. The receiver might overheat.

If the stator leads cannot be disconnected easily, another method of zeroing a receiver may be used. Set the transmitter to zero. Connect a temporary jumper from S1 to S3. This will hold the receiver on zero. Now set its dial to zero. Either unclamp the case of the receiver and turn the receiver until the dial reads zero or loosen the dial and turn the dial to zero. Clamp the receiver in position or tighten the dial, whichever is the case. Remove the jumper.

One method of zeroing a transmitter is to connect it to a receiver having a dial to show when its shaft is at the electrical zero position. This may be either a portable unit or a receiver already in the synchro system. However, the receiver must be correctly zeroed in either case.

The transmitter is connected to the receiver in the normal manner. Set the antenna, transducer, or other unit, whose position the transmitter transmits, accurately in its zero position. Then unclamp the transmitter and turn the stator housing until the receiver reads zero. The

transmitter is now set approximately on zero. To check for the exact zero position momentarily connect a jumper between S1 and S3. If the receiver shaft moves at all when this is done, the transmitter is not exactly zeroed. Shift the transmitter case slightly and connect S1 and S3 again. This is repeated until the receiver shaft does not move. When the transmitter is accurately zeroed, remove the jumper and tighten the clamp.

Zeroing a differential receiver is similar to the procedure for zeroing a synchro receiver, since the shaft of a differential receiver usually is free to turn. Disconnect all the leads. Connect S2 and R2 to one side of the 115-volt a-c line. Connect S1, S3, R1, and R3 to the other side of the 115-volt a-c line. The shaft will turn to its electrical zero position. Set the dial to zero while the differential receiver is connected in this manner. Do not leave it connected very long, since the unit may overheat.

In figure 12-11, assume that the transmitter and the receiver have already been zeroed. Set to zero the unit whose position the differential transmitter is to transmit. Place a jumper between S1 and S3 of the differential transmitter. Unclamp the stator housing and turn it until the receiver reads zero. The differential transmitter is now approximately on zero. To check for the correct position, momentarily connect a jumper between R1 and R3. If the receiver shaft turns at all when this is done, the differential transmitter is not exactly on zero. Shift the stator housing slightly and try again until the zero position is obtained. When the differential transmitter is accurately zeroed, remove the jumper and tighten the clamp.

A control transformer may be zeroed by using an a-c voltmeter. Remove all the leads connected to the control transformer. Connect 115 volts a-c between S1 and S3. No connection is made to S2. Connect R2 to S3. Place a voltmeter, with its scale set on at least 200 volts, between

R1 and S1. Unclamp the control transformer and turn it until the voltmeter indicates minimum, which is about 40 volts. Now change all the connections. Connect the voltmeter between R1 and R2. Connect S1 to S3. Connect 115 volts a.c. between S1 and S2. Set the voltmeter to a low range. Turn the control transformer until the meter reading is minimum. Clamp the unit in this position and reconnect the leads in their normal order. Do not leave the control transformer connected to the 115 volts longer than necessary or it may overheat.

## TROUBLE-SHOOTING

In many synchro systems trouble may be located easily by watching the incorrect action of the receivers and checking a few other symptoms. There are several common troubles associated with synchro systems such as incorrect wiring, shorted rotor or stator, open rotor or stator, and mechanical jamming of gears used with synchros. There are two things to remember about synchros. If they are working, leave them alone. If a unit is faulty, replace it.

Table 1 applies to a system where a single transmitter feeds several receivers. If the symptoms mentioned appear in all the receivers, the trouble is in the transmitter or the main bus feeding the receivers. If the symptoms appear in only one receiver, the trouble is in that receiver. The angles mentioned in the table are not valid in a system containing differentials nor in a system where receivers are not correctly zeroed.

More complete information about synchros and trouble-shooting synchros can be found in *U. S. Navy Synchros, OP 1303*.

TABLE 1.—*Synchro Troubles*

Indications	Cause
<b>OPEN CIRCUITS:</b>	
Poor torque—synchro can follow sluggishly either in synchronism or 180° out of synchronism.	R1 or R2 open.
As the transmitter is rotated 360° the receivers oscillate between 60° and 180° or between 240° and 300°. The position of oscillation depends upon the position of the system when the open occurs.	S1 open.
As the transmitter is rotated 360°, the receivers oscillate between 120° and 240°.	S2 open.
As the transmitter is rotated 360°, the receivers oscillate between 0° and 120° or between 180° and 300°.	S3 open.
All receivers oscillate.....	Open in transmitter.
One receiver oscillates.....	Open in that receiver.
<b>SHORT CIRCUITS:</b>	
Blown fuses.....	R1 and R2 shorted.
Entire system locks at 0° or 180° depending upon the position of the system when the short occurs. Spinning may occur.	S1 and S3 shorted.
Entire system locks at 60° or 240°.....	S1 and S2 shorted.
Entire system locks at 120° or 300°.....	S2 and S3 shorted.
Entire system spins.....	S1, S2, and S3 shorted.
<b>WRONG CONNECTIONS:</b>	
Receiver follows 180° out.....	R1 and R2 reversed.
No shift of electrical zero, but wrong direction of rotation.	S1 and S3 reversed.
Electrical zero shifts to the 120° position and wrong direction of rotation.	S1 and S2 reversed.
Electrical zero shifts to 240° position and wrong direction of rotation.	S2 and S3 reversed.
<b>OTHER TROUBLES:</b>	
Jerky motion of the pointer or spinning.....	Faulty bearings.
Excessive oscillation or spinning.....	Damper trouble.
One receiver stops, all other receivers read in error.	Rotor jammed.
Humming.....	Worn bearings.

## QUIZ

1. What is a synchro?
2. How are the stator windings of a synchro generator and receiver connected?
3. Under what conditions is the effective current in the connecting lines between a transmitter and a receiver zero?
4. How many groups of coils comprise the stator windings of a receiver and how are they spaced?
5. What are the markings of the three free ends of the stator windings?
6. What is the mechanical difference between a transmitter rotor and a receiver rotor?
7. What is the highest voltage (rms) that can be induced in any one stator coil?
8. Why is the stator of a differential always connected as the primary?
9. What is the principal use of a control transformer?
10. The control transformer rotor is not connected to an a-c supply. How does it receive its voltage?
11. Why is no inertia damper required on the shaft of the control transformer rotor?
12. When the axis of the rotor coil is  $90^\circ$  out of alinement with the axis of the stator field, how much voltage is induced in the rotor of a control transformer?
13. What is the purpose of a synchro capacitor?
14. Where is a synchro capacitor usually located in a synchro system?

## **BASIC PRINCIPLES OF SONAR**

### **MEANING AND USE OF SONAR**

The word “sonar” is a combination of the first letters of the words “SOund Navigation And Ranging.” Sonar is essentially echo ranging under water. It includes searchlight sonar and scanning sonar, which are discussed in chapters 14 and 15, respectively. Sonar listening equipment also is described in chapter 15. Any sonar echo-ranging equipment becomes sonar listening equipment by disabling the transmitter.

On surface ships, sonar is used to detect submarines, other ships, and objects in the water. On submarines, sonar is used to detect ships, other submarines, and objects in the water. The basic principle of sonar is similar to that of radar except that radar uses electromagnetic waves while sonar uses sound waves. A short pulse of energy is transmitted. An observer determines the length of time between the transmission of the pulse and the receipt of an echo (reflected sound energy). Since the velocity of the transmitted pulse is known and the time of travel can be measured, the range of the target can be computed.

### **PROPAGATION OF SOUND**

Sound waves are compression waves propagated through a medium which may be a liquid, a gas, or a solid.

Sound does not travel in a vacuum. Figure 13-1 shows the way spherical sound waves are produced. The source of the sound waves is the transducer. It has a diaphragm which is caused to vibrate. When the diaphragm of the transducer moves out, the medium next to it is compressed. If the diaphragm now moves back, the particles in the medium move apart causing a rarefaction or low

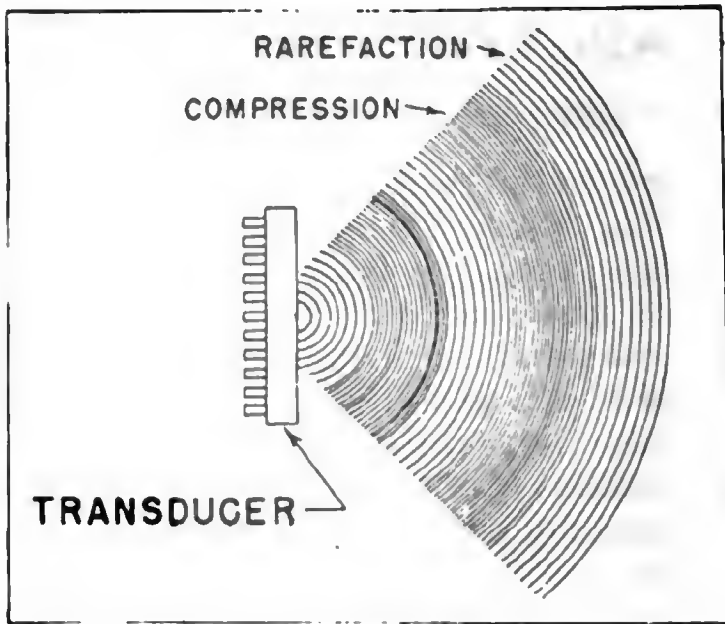


Figure 13-1.—Producing sound waves.

pressure area next to the diaphragm. As the diaphragm again moves out, a new compression pushes the first compression and rarefaction farther out. As this out-and-in movement of the diaphragm continues, a spreading series of alternate compressions and rarefactions is set up.

The wavelength of a sound wave is the distance between two successive rarefactions or compressions. The number of wavelengths (cycles) per second is the frequency. The human ear is sensitive to sound waves with frequencies ranging from approximately 20 to 15,000 cycles per second. Vibrational waves with frequencies



below 20 cycles are known as SUBSONIC WAVES while waves with frequencies above 15,000 cycles are known as ULTRASONIC WAVES. In sonar, ultrasonic waves are generally transmitted. Frequencies of 18,000 to 40,000 cycles are commonly used in sonar.

To locate a target effectively by means of reflected sound energy, the sound must be projected in the form of a narrow beam. This is achieved by a large source. A purely spherical wave is produced by a point source. It spreads out evenly in all directions. Ultrasonic waves are usually propagated as plane waves.

The velocity of sound is equal to the frequency multiplied by the wavelength. In equation form this may be written

$$c = \lambda f,$$

where  $c$  is the velocity of propagation,  $\lambda$  is the wavelength, and  $f$  is the frequency in cycles per second.

The velocity of sound in a medium is, among other things, directly proportional to the temperature of the medium. The velocity of sound in air is about 1090 feet per second at 0° C and increases about 2 feet per second for each degree centigrade increase in temperature. The velocity of sound in water is more than 4 times that in air. In sea water the velocity of sound increases from about 4700 feet per second at 30° F to 5300 feet per second at 85° F.

The wavelength of a sound wave is equal to the velocity divided by the frequency. In air, a 20,000-cycle sound wave has a wavelength of about two-thirds of an inch. In salt water a sound wave of the same frequency has a wavelength of about 3 inches. Because of the relatively short wavelength of ultrasonic waves, the wave motion usually travels almost in a straight line. The sound energy cannot travel around sharp corners. This property of ultrasonic waves makes them useful in locating small objects.

## REFLECTION AND REVERBERATION OF SOUND

When a sound wave traveling through water strikes an object, or a boundary between the water and some other medium, the rays may not penetrate the medium. Rather they may bounce off at an angle equal to the angle at which they struck. This is called REFLECTION. In water less than 600 feet deep there may be reflections from the bottom of the body of water. Sound may be reflected also from the surface of the water. If the sea becomes rough, reflections from the surface take place in so many directions that the general effect is that of SCATTERING.

Reflections from the surface of the water, from the bottom of the body of water, and from air bubbles and foreign matter in the water combine to form reverberations. Since these reflections come from various ranges, there seems to be a continuous sound which is strong at first and gradually fades away. Reverberations from nearby points may be so strong that they interfere with echoes from nearby targets.

Three types of reverberations are recognized in sonar. The first type is sound reflected from the mass of water. The cause of this reflection is not completely understood. The second type of reverberations is sound reflected from the surface of the water. This sound is most intense right after transmission. The third type of reverberations is sound reflected from the bottom of the body of water. In shallow water these reverberations are the most intense of the three types, especially when the bottom is rocky.

## LOSS OF SOUND ENERGY

If sound waves were to travel through an ideal medium, there would be no loss of sound energy. The ocean is not an ideal medium. The loss of energy during the passage of an ultrasonic wave is called ATTENUATION. It includes loss by absorption and loss by scattering.

An ideal medium for the travel of sound would be perfectly elastic, infinite in extent, and homogeneous. Perfect elasticity means that the medium, when distorted or displaced, returns to its original shape without any loss of energy by internal friction. The infinite extent of the medium eliminates the necessity of considering reflections from the boundaries of the medium. Homogeneous means that characteristics such as temperature, density, pressure, and salinity are the same throughout the medium.

As a sound wave travels through sea water, some of the energy is converted into heat energy because of friction. This loss is called ABSORPTION. The amount of sound absorption depends on the state of the ocean. It is high when the winds at the surface are strong enough to produce whitecaps, which represent a concentration of air bubbles at the surface. Absorption also is much greater in the wakes of ships and in strong currents.

If an obstacle in the water is very small, ultrasonic energy may pass around it as though there were no interference. If there are many small obstacles such as air bubbles, silt, sea weed, or animal life, a large amount of the energy will be scattered. Instead of being reflected, much of the energy seems to disappear inside the mass of obstacles.

When a wave traveling through one medium impinges on a boundary between it and a second medium, splitting may occur. Part of the energy travels forward through the second medium while part of the energy is reflected back into the first medium. This usually happens when a sound beam traveling through a layer of water of constant temperature strikes a layer in which the temperature is lower.

Sea water is not a homogeneous mass. Its density varies with temperature and salinity. Just as temperature has the greatest effect on the velocity of sound, it also

is the principal factor affecting density. The salinity of sea water is fairly constant except near the mouths of large rivers, where it is less. Salinity seems to have a greater effect on density than on the velocity of sound. The effect of the small changes in salinity is usually neglected. The effect of pressure is not particularly noticeable, except at great depths where the temperature is nearly constant. In this case pressure causes the velocity of sound to increase with depth.

## REFRACTION OF SOUND

When a sound beam enters a medium in which the velocity of sound changes, the rays have a tendency to bend. This bending is called REFRACTION. The principal factor affecting the velocity of sound in sea water is temperature. In the ocean, horizontal variations in temperature are usually small. The ocean may be thought of as being made up of layers, the upper layers usually being warmer than the lower layers. Cooler water is more dense than warmer water and the velocity of sound is less in cooler water. As a sound wave passes from a layer in which the velocity of sound is lower to a layer in which the velocity of sound is higher, the sound rays bend toward the layer of lower velocity.

In the ocean a sound beam usually does not travel in a straight line for a great distance. Instead it follows a curved path because the temperature of the water is changing continuously with depth. The rays are being continually refracted.

When the temperature of the layers in the ocean increases with depth, the phenomenon is called POSITIVE TEMPERATURE GRADIENT. When, on the other hand, the temperature decreases with depth, the phenomenon is called NEGATIVE TEMPERATURE GRADIENT. Figure 13-2, A, shows the effect of a positive temperature gradient on a sound beam. This condition is not common, but may

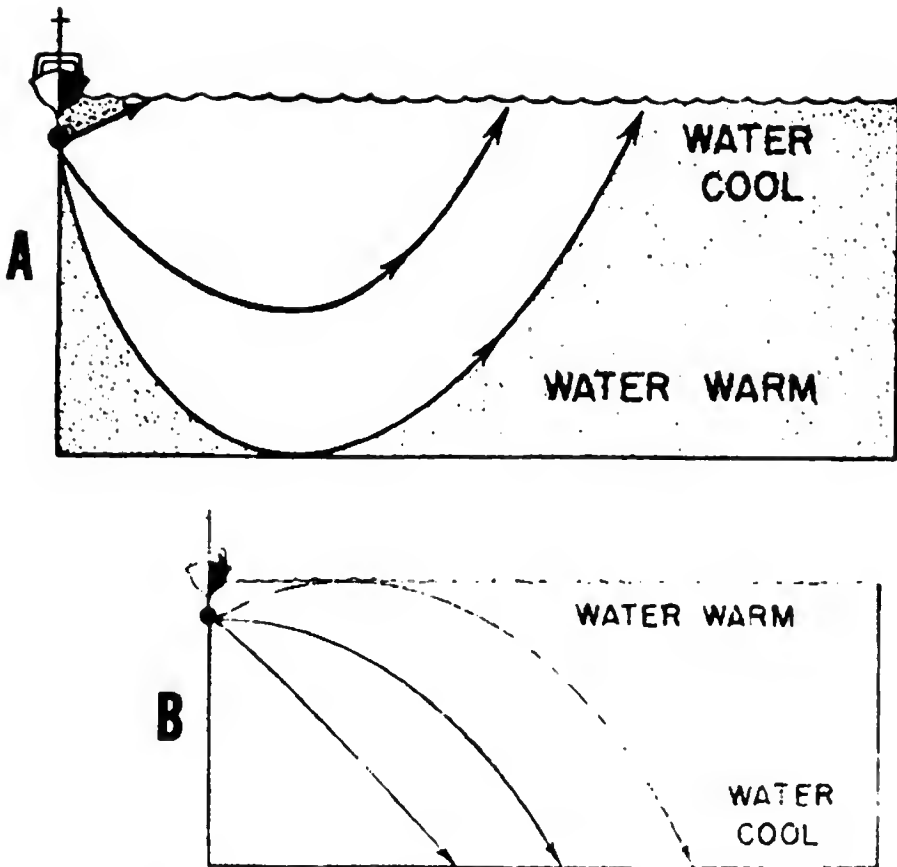


Figure 13-2.—Effect of the temperature gradient. A, Positive gradient, B, negative gradient.

occur. The sound beam bends upward away from the warmer water. Figure 13-2, B, shows the effect of a negative temperature gradient. The sound beam is bent downward, again away from the warmer water.

An **ISOTHERMAL** layer is a relatively thick layer of water which has a constant temperature. Often there may be an isothermal layer which extends several hundred feet below the surface of the water. The deeper an isothermal extends, the better the sound conditions. Figure 13-3 illustrates the increased range that may be obtained when an isothermal is encountered. Below an isothermal there often is a layer of sea water in which the temperature decreases rather rapidly. A layer with a sharp negative temperature gradient is called a **THERMOCLINE**.

Refraction is the most outstanding factor affecting the sound beam from a transducer. A beam would travel in a pattern similar to that shown in figure 13-4, A, if the temperature of the water were the same at all depths. As indicated, the sound would spread out and be weakened by absorption at a constant rate. Such ideal sound conditions are never present. Refraction limits the sonar range regardless of power at the source. It may reduce the range at which a submarine can be detected to less than 1000 yards (figure 13-4, B). The range may change sharply with changing submarine depth. Submarine commanders take advantage of the effects of refraction during evasive action.

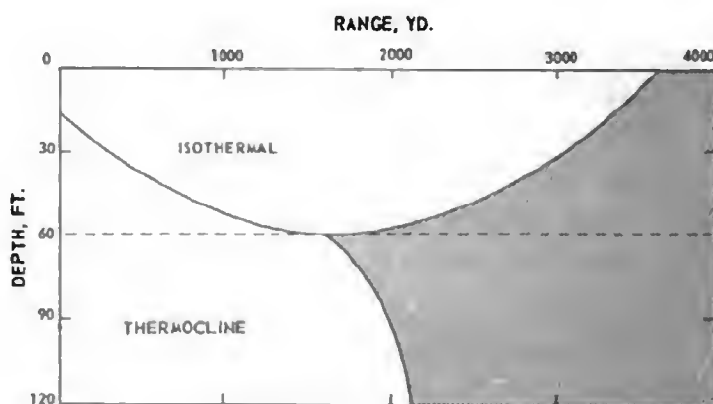


Figure 13-3.—Effect of an isothermal.

## BATHYTHERMOGRAPH

Sound conditions in the ocean can be predicted, if the temperature of the water at different levels is known. The bathythermograph (BT) is a sensitive recording thermometer which is lowered into the water. A simplified drawing of a BT is shown in figure 13-5. The BT, while being lowered from a ship, automatically draws a graph of the temperature as compared to depth. Ordinary thermometers are not as useful as the BT because they record the temperature at only one depth.

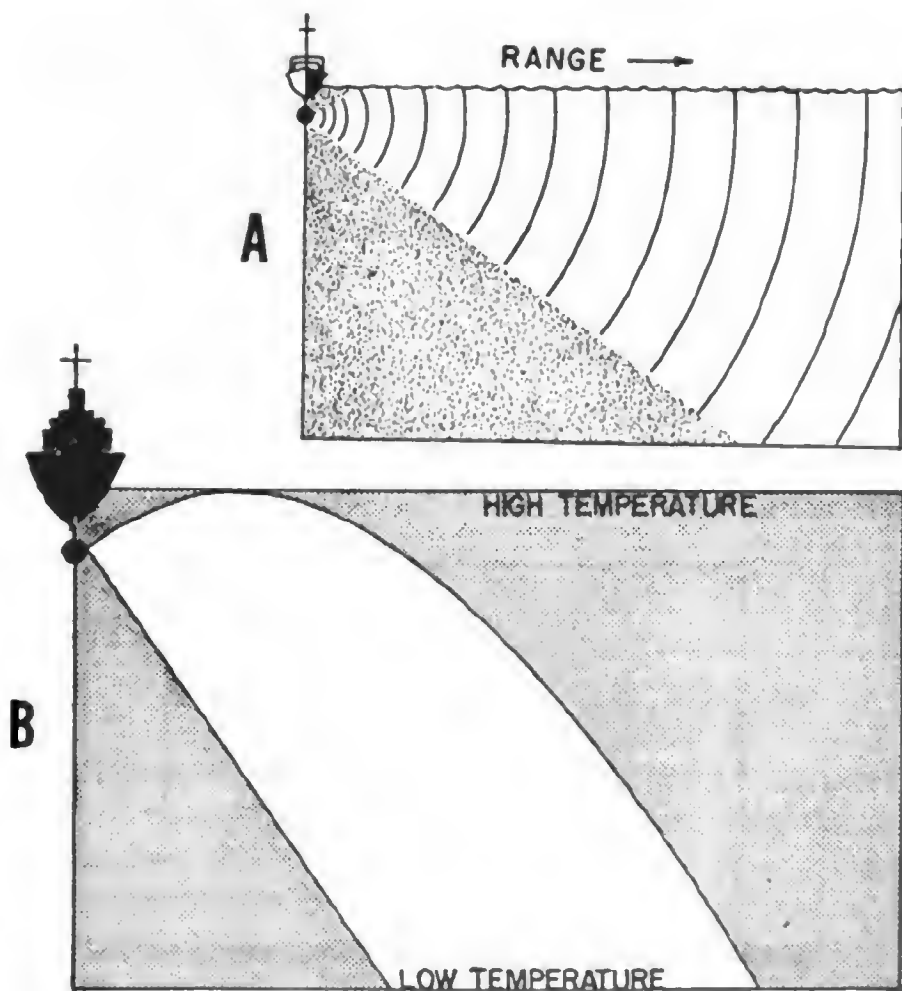


Figure 13-4.—Refraction. A, Sound beam in water of constant temperature, ideal sound conditions; B, refraction of the sound beam.

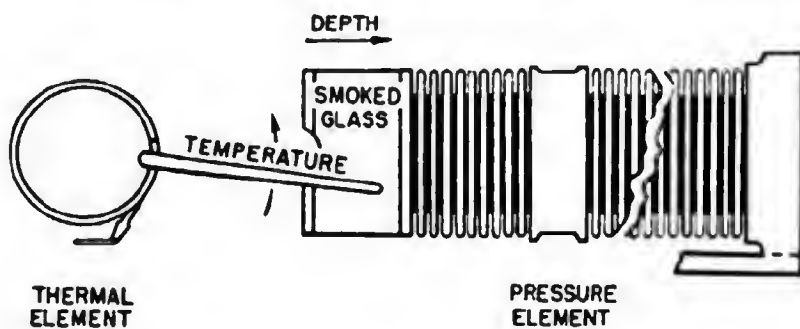


Figure 13-5.—Construction of a bathythermograph.

As the BT is lowered, a stylus is moved vertically over a smoked slide by the thermal element, which is activated by the expansion or contraction of the liquid inside the element. Increasing hydrostatic pressure compresses a bellows which moves the smoked slide horizontally. The temperature and depth are thus recorded simultaneously on the slide.

After the BT is raised, the slide is removed and dipped into fresh water. The slide is then labeled and dipped into lacquer to preserve it. When the slide is to be read, it is placed in a viewer as shown in figure 13-6.

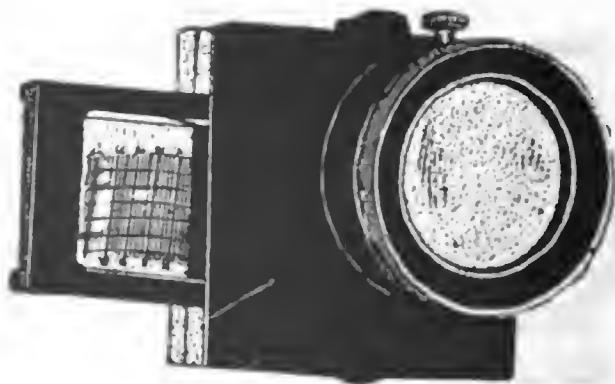
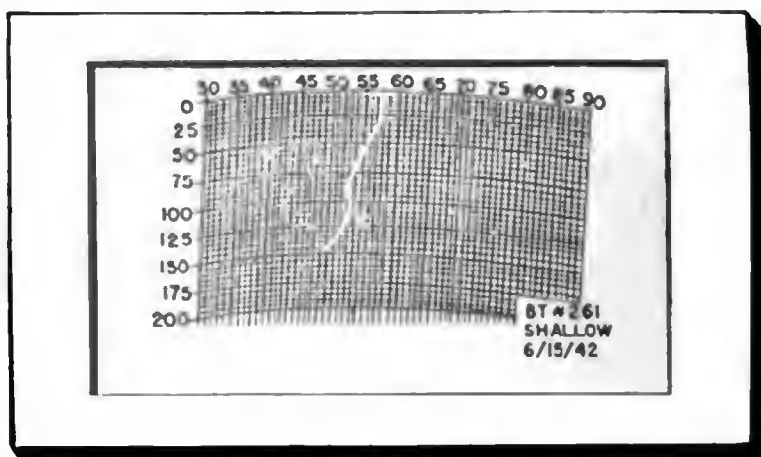


Figure 13-6.—Viewer and grid used in reading BT slides.



Several examples of the graphs drawn on slides by a BT are shown in figure 13-7. The horizontal line at the

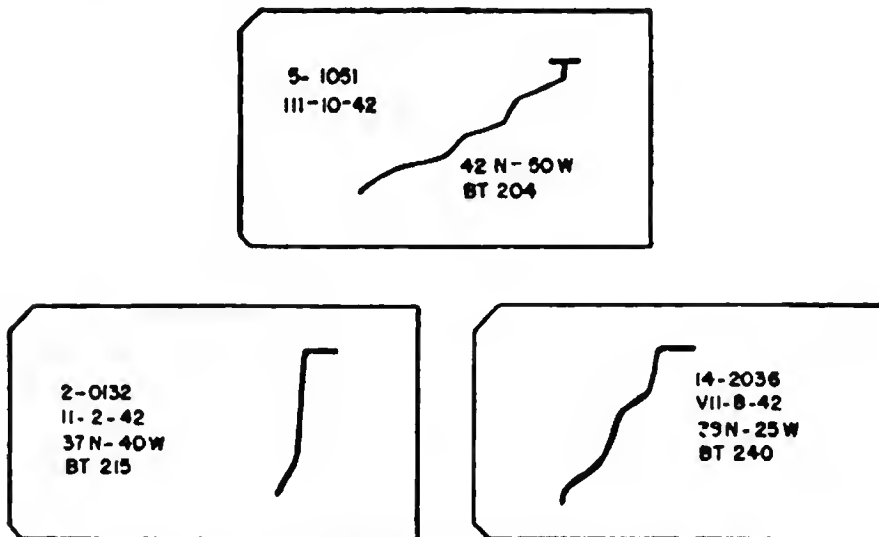


Figure 13-7.—Examples of bathythermograph slides.

top of the slide indicates the temperature at the surface. The letters and numbers on the slide are for identification. On the first line is the slide number and the Greenwich mean time when the BT was lowered. The second line shows the date, the month being written in roman numerals. The third line gives the latitude and longitude to the nearest degree. The fourth line is the serial number of the BT.

## BACKGROUND NOISE

In the application of sonar the use of listening equipment is necessary. The listening-equipment operator depends primarily on his ears to distinguish different noises. His task is to detect and recognize a wanted signal against background noise. There are two types of background noise—AMPLIFIED NOISE and AIRBORNE NOISE. Amplified noise is noise reproduced by the headphones or loudspeaker. Airborne noise is any noise other than that coming from the loudspeaker or headphones.

A listening equipment in its simplest form could consist merely of a watertight microphone (hydrophone) lowered into the water and connected to an amplifier. As a first step the operator distinguishes between airborne noises and amplified noises. A signal from the hydrophone can be made more perceptible by increasing the gain of the amplifier, since sound from the headphones is thereby further amplified while the level of the airborne noises remains the same.

A desired signal is but one of many sounds that are amplified and heard by the operator. Amplified noises originate in the sea and in the listening vessel itself. They constitute a masking background for the desired signal. Increasing the gain of the amplifier does not help because this also further amplifies the unwanted noises.

Amplified noise results from movement of the hydrophone diaphragm, vibration of own ship, propeller noise, and turbulence of the water around the diaphragm. Still another type of amplified noise is AMBIENT NOISE. This type includes noise due to the wave motion at the surface of the water, biological noise caused by marine life, and traffic noise which is noticeable in busy harbors.

Many species of marine life produce sounds of various types. These sounds are undesirable when a person is attempting to detect ships and submarines. The chief noise makers among fish are certain types of croakers and drumfish.

In an experiment it was observed that, as a ship was approaching shallow water, the ordinary ambient noise was sometimes replaced by sounds resembling the sizzle of frying fat. As the ship came closer to shore, the sound approximated the crackle of burning twigs or crashes of static as heard in a radio receiver. This noise was encountered only in tropical and subtropical regions. Investigation showed that this noise was due to colonies of a

certain species of snapping shrimp that close their pincers with a loud click.

Listening equipment is more useful on submarines than on surface ships because of the lower noise level on submarines. A surface vessel traveling at high speed makes a great deal of noise, which masks sound originating outside the vessel.

## MAGNETOSTRICTION

Some of the transducers used with sonar equipment operate on the magnetostriction principle. Certain substances such as nickel and iron change their dimensions as they are magnetized. This phenomenon is called **MAGNETOSTRICTION**. The magnetostriction transducer operates on the principle that the length of a nickel tube or rod decreases when the tube or rod is placed in a magnetic field. The change in length is very small and, within limits, is proportional to the strength of the magnetic field. It is independent of the direction of the magnetic field.

Magnetostriction effect on a nickel rod is shown in figure 13-8. The nickel tube or rod is surrounded by a coil of wire. At A in the figure may be seen a tube and coil without any excitation. Notice the length of the tube. Several tubes and coils are shown at B. The coils are excited with a 25-kc signal, and the varying magnetic field about each tube decreases the length of the tube as the field strength increases. The length decreases twice for each cycle of a-c excitation, once on the positive alternation and once on the negative alternation. This doubles the frequency.

To eliminate frequency doubling, the tubes are subjected to a constant magnetic field (part C of the figure) supplied by either permanent magnets or by direct current flowing through the coils. This polarizing field pre-

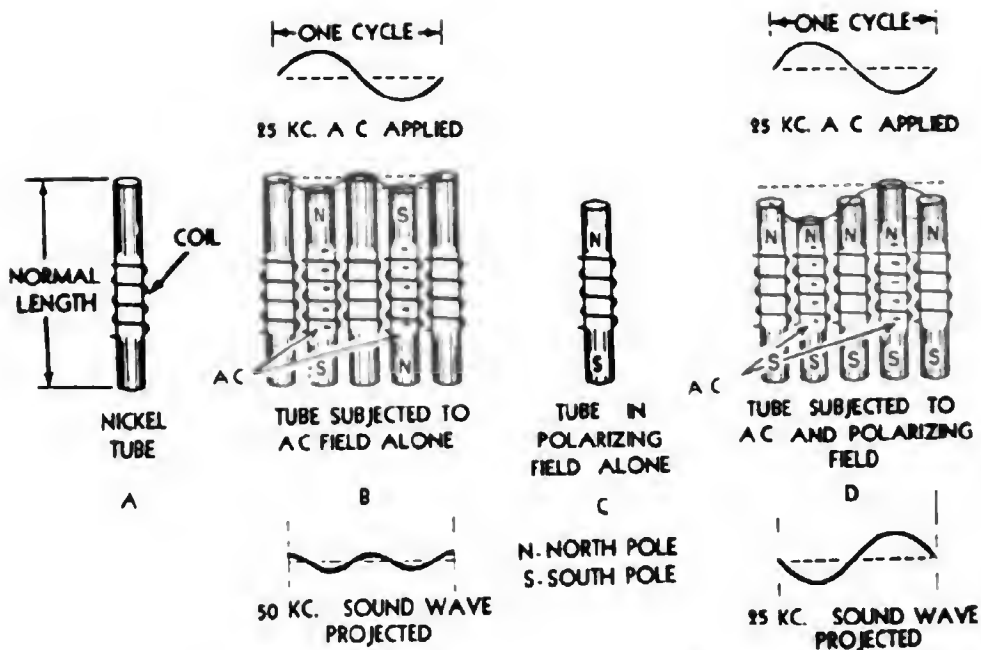


Figure 13-8.—Magnetostriction effect.

vents the frequency from doubling because it fixes the polarity of the tubes.

The effect of the polarizing field is shown at D in figure 13-8. The initial effect of the polarizing field is to shorten the lengths of the tubes. After the polarizing field is applied, the tubes can be made still shorter or they can be made longer by the a-c excitation. A tube can never be made longer than it was originally without any polarizing field.

The addition of the a-c excitation aids the polarizing field on the negative alternation. Thus, the field around the tube is increased on the positive alternation, resulting in a shortening of the tube. The field is decreased on the negative alternation, resulting in a lengthening of the tube.

In addition to preventing frequency doubling, the polarizing field causes a greater variation in the lengths of the tubes for an alternating current of a given ampli-

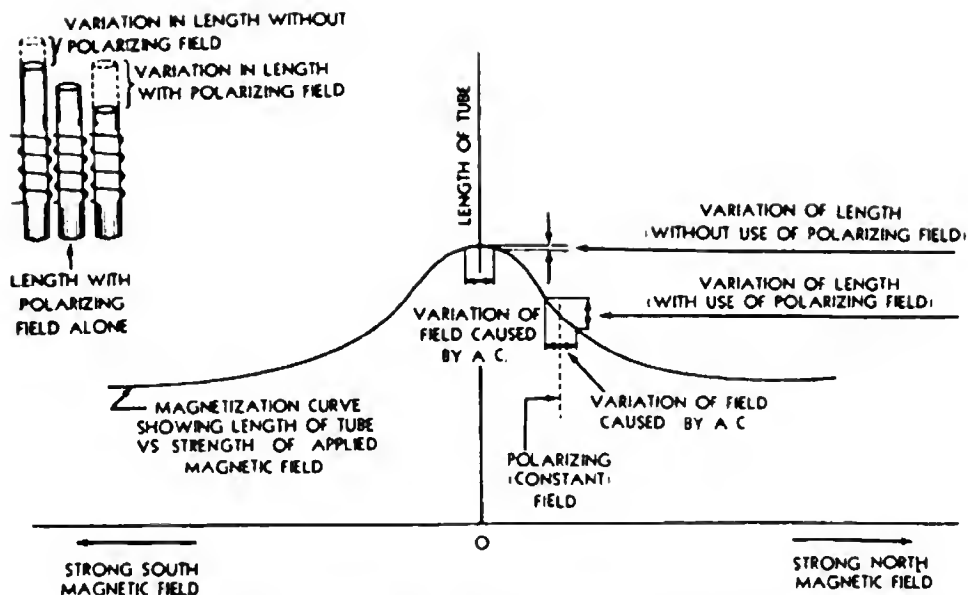


Figure 13-9.—Graph showing the effect of a polarizing field.

tude. The vibrations for a given current thus have a greater amplitude. This is shown in figure 13-9.

A magnetostriction transducer used with sonar equipment is made up of a large number of tubes and coils, usually connected in a series-parallel arrangement. A cut-away view of such a transducer is shown in figure 13-10. One end of each tube is attached to the diaphragm which is in contact with the sea water.

The polarizing field is obtained from permanent magnets. The transducer changes the alternating current to sound energy at the same frequency and forms the sound energy into a beam. When an echo strikes the diaphragm, the lengths of the tubes change and a voltage is induced into the coils surrounding the tubes. The voltage induced into the coils is fed to a receiver where it is amplified and then fed to display devices or converted into audible frequencies and fed to a loudspeaker.

## PIEZOELECTRIC EFFECT

Certain sonar equipments use crystal transducers. The operation of a crystal transducer is based on the PIEZO-

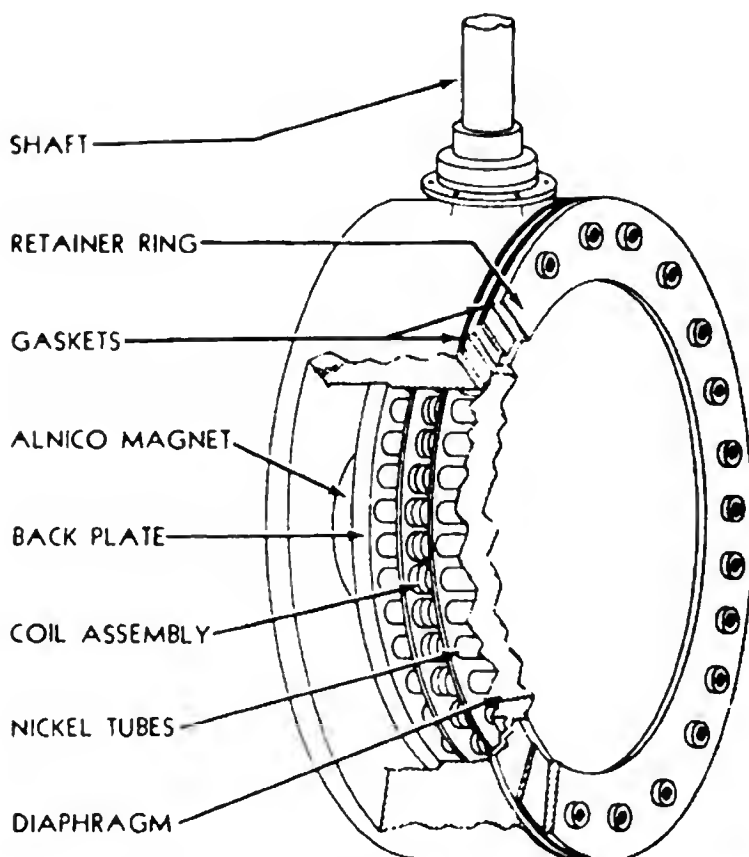


Figure 13-10.—Cut-away view of a magnetostriction transducer.

**ELECTRIC EFFECT** of certain crystals. This is the property, which some crystalline substances have, of changing their physical dimensions when they are placed in an electrostatic field. The change is due to the realignment of the molecules of the crystal in relation to the stress placed upon it. The realignment causes the crystal to shorten along one axis and lengthen along another axis.

The piezoelectric effect works also in reverse—that is, if the crystal is subjected to mechanical pressure, a voltage will be present across two of its faces. A few of the substances which exhibit the piezoelectric property are Rochelle salts, ADP (ammonium dihydrogen phosphate), and quartz.

An exploded view of a crystal transducer is shown in

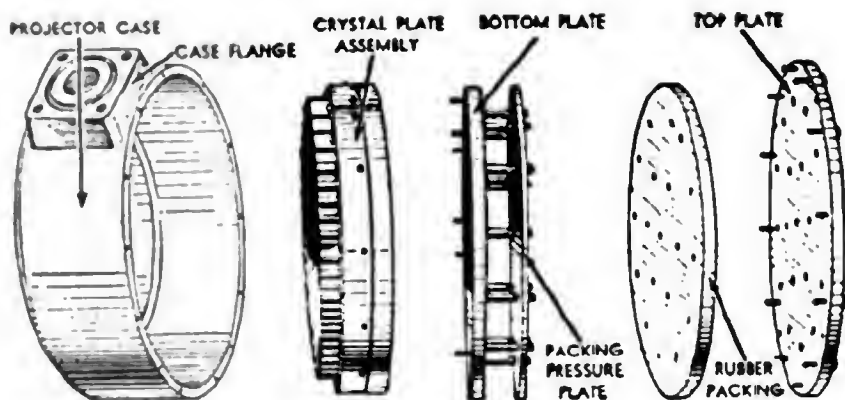


Figure 13-11.—Exploded view of a crystal transducer.

figure 13-11. The crystals are cemented to a backing plate. When the backing plate is placed in the transducer case, the crystals do not touch the diaphragm. The space between the crystals and the diaphragm is filled with castor oil, which protects the crystals from moisture and serves as a sound medium almost identical to sea water.

Each crystal has thin silver electrodes mounted on two opposite faces. These electrodes are connected in a parallel circuit. During transmission, a voltage is placed across the crystals, causing them to change their length. A crystal transducer produces sound energy at the same frequency as that of the voltage used to excite it.

## DOPPLER EFFECT

The sound sent out by a sonar transmitter has a certain given frequency. If the distance between the source and the receiver of sound is changing, the frequency of the source of the sound energy seems to change. This change in frequency is known as the **DOPPLER EFFECT**. As soon as the relative motion between the source and the receiver ceases, the Doppler effect is no longer present. The Doppler effect is useful in determining whether the distance to a target is increasing, decreasing, or remaining constant.

Suppose that sound travels out from a transducer and an echo is received from a submarine. If the distance between the sonar transducer and the submarine is changing, the frequency of the echo will be different from the transmitted frequency. A submarine moving toward the transducer will cause the frequency of the echo to be greater than the frequency of the outgoing pulse. If the submarine is moving away, the frequency of the echo will be less than that of the outgoing pulse.

In present-day equipment the receiver is generally muted during transmission so that the operator does not hear the outgoing ping. Instead of comparing the frequency of the echo with the frequency of the outgoing ping, it is compared with the frequency of the reverberations received immediately after the end of the outgoing ping. By comparing the frequency of the echo with the frequency of the reverberations, the effect of own ship movement is eliminated. No matter whether the range is opening or closing, if the target is moving toward the transducer, the frequency of the echo will be greater than the frequency of the reverberations (called "up-doppler"). If the target is moving away from the transducer, the frequency of the echo will be less than the frequency of the reverberations ("down-doppler"). Note that Doppler effect is observed only during the time when a change in range is occurring.

## NMC-2 FATHOMETER

Fathometers are quite similar to echo-ranging sonar equipment. The major difference is that, instead of being used to determine the range of a target, the fathometer is used to determine the depth of the water. There are several different types of fathometers. Some types use a crystal transducer while others use a magnetostriction transducer. The NMC-2 fathometer is discussed in this chapter.



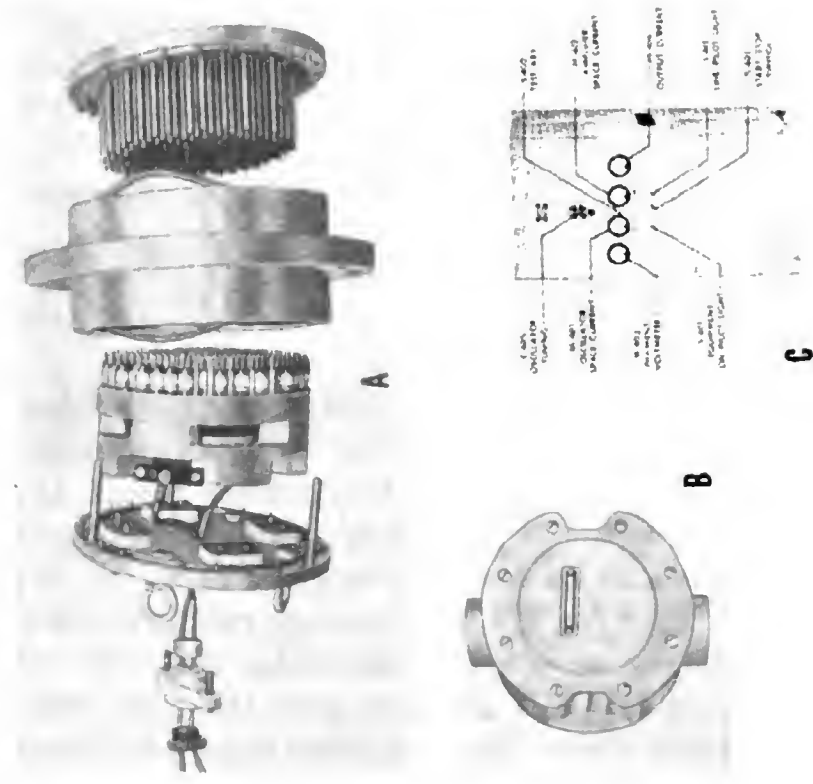


Figure 13-12.—Units of the NMC-2 fathometer. A, Transducer; B, transducer junction box; C, driver-rectifier; D, indicator-recorder.

The units that comprise the NMC-2 fathometer are shown in figure 13-12. The transducer (figure 13-12, A) is a magnetostriction type using permanent magnets for polarization. It is mounted on the bottom of a ship, with the diaphragm parallel to the surface of the water.

The transducer junction box (figure 13-12, B) contains a capacity network for power-factor correction. The transducer presents a high inductive load to the driver. This causes large reactive currents to flow through the leads to the transducer. The capacitors in the junction box reduce the reactive current and increase the power factor.

### **Power Supply**

A schematic diagram of the NMC-2 is shown in figure 13-13. The duplex-bridge power supply for the transmitter provides two different plate voltages, one for the oscillator and one for the amplifier. The power supply uses two tubes (V407 and V408) and transformer T406 as a full-wave rectifier to supply the oscillator and four tubes (V407, V408, V409, and V410) and transformer T406 as a bridge rectifier to supply the amplifier. This power supply is similar to that used in the TDZ transmitter described in chapter 5.

### **Control Circuit**

The control circuit in the NMC-2 fathometer is similar to control circuits used in various other equipment. Pressing the start button closes relay K401. This places 110 volts a-c across K403. The closing of relay K403 causes voltage to be applied to the primary of T405, to the filament transformer for the high voltage rectifier tubes, and to the primary of T407 (energizing the -75-volt bias supply). Closing K403 also energizes the time delay heater unit in relay K404. The time delay allows sufficient



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time for the filaments of the high voltage rectifier tubes to heat before plate voltage is applied.

As soon as the time delay relay closes, the output of the bias rectifier energizes relay K406. The contacts of K406 close and apply voltage to the primary of T406. If for any reason the bias voltage is removed, the high voltage supply is deenergized. Further, when relay K401 closes, voltage is applied to the primary winding of each of the transformers T301, T302, T402, and T501, to the blower motor, and to the indicating lamps. Pressing the stop button removes the voltage across K401, deenergizes the other relays, and shuts down the equipment.

### **Driver**

The driver (figure 13-12, C) of the NMC-2 consists of a push-pull Hartley oscillator driving a push-pull parallel power amplifier. The frequency determining components of the oscillator are the three capacitors C403, C404, and C405, and transformer T401. Capacitor C405 is variable and is used to adjust the oscillator frequency. The oscillator tunes between 17 and 19 kc. The output of the oscillator drives the power amplifier. The output of the power amplifier is developed across T403. The secondary is connected to the projector.

### **Receiver-Amplifier**

The receiver of the NMC-2 consists of two push-pull r-f amplifiers, a detector, a BFO, and two audio-amplifier channels.

The receiver-amplifier input is connected across the secondary of T403. Therefore, the full output of the driver is applied to the input of the receiver. When the driver is keyed, two means are used to protect the receiver input circuit. First, resistor R101 limits the amount of grid current of the first amplifier stage. Second, the

gas tube V110 ionizes, shunting the secondary of the input transformer. The gas tube ionizes when the driver is keyed, but it is not ionized when echoes are received. The sensitivity control R302, located in the indicator unit, controls the gain of the first r-f stage by changing the bias applied to the cathodes. The r-f stages are tuned by the ganged variable capacitor C101.

Tube V107 is the beat frequency oscillator (BFO) tube. Its output is connected to the suppressor grids of the detector (V105 and V106). The input to the detector, from the second r-f amplifier, and the output of the BFO heterodyne to produce an audio frequency. Capacitor C136 may be adjusted to vary the frequency of the beat note by varying the frequency of the BFO.

When the VISUAL-AUDIBLE switch S302 is in the VISUAL position, the detector output is connected by relay K102 to the red-light amplifier stage V108. The output of the detector is developed across resistor R121. The load for V108 is step-down transformer T105. The secondary of this transformer is connected to the primary of transformer T301 which steps the voltage up to about 800 volts. The voltage is applied across a neon lamp I301 in the indicator unit.

The neon lamp and an incandescent lamp I301A are mounted on a timing disk rotating behind a fixed dial. (Operation and use of I301A is explained later in this chapter.) These lamps are fed through slip rings. The driver is keyed when the neon lamp is at the position on the dial corresponding to zero depth. The mark indicating zero depth is located at the top of the dial.

A returning echo causes the neon lamp to flash. Since the speed of rotation of the disk and the velocity of sound in sea water are known, the dial can be calibrated directly in units of depth, such as feet or fathoms. After the sound pulse is transmitted, the neon lamp continues to rotate. When an echo is received, the lamp flashes at

the position on the dial corresponding to the depth of the water.

Placing S302 in the AUDIBLE position operates relays K101 and K102. This switches the detector output to the white light amplifier V109. The output of the white light amplifier is applied to the phone jack and to the speaker through the contacts controlled by the phone cut-out eccentric. The setting of BIAS CONTROL R125 determines the echo amplitude necessary to produce a visual output. This control is used to adjust the bias applied to the detector.

### Indicator-Recorder

The INDICATOR-RECORDER of the NMC-2 is shown in figure 13-12, D. A timing disk rotates behind the dial. Either the neon lamp or the white lamp shows through the space between the two scales on the dial. The position of the visual-audible switch determines the method of sound employed.

For visual (automatic) sounding, the neon lamp flashes at the instant the echo is received. The position at which the lamp flashes indicates the depth of the water in fathoms. When the VISUAL-AUDIBLE switch is in the AUDIBLE position, an incandescent (white) lamp shines continuously behind the dial.

For audible sounding, the transmitter is keyed in the same manner as for visual sounding. However, in audible sounding the operator listens for returning echoes. The instant he hears an echo from the bottom he notes the position of the white light on the dial. This position corresponds to the depth.

Audible sounding is sometimes used when high reverberations would cause the neon lamp to flash several times or even remain continuously lighted. Also when the returning echo is too small to flash the neon lamp, audible sounding is desirable.

The recorder of the NMC-2 is located on the right-hand side of the indicator-recorder. The recorder indicates the depth only when the visual-audible switch is in the VISUAL position and the SIGNAL-INTERVAL switch is in the 400-2000 position. A chemically treated paper is moved under a stylus. This paper is sensitive to electric current. If current is passed through the paper, a chemical reaction takes place which causes a black mark to appear at the point where the current passed through.

Generally, in this type of recorder the stylus marks the paper only at the time when a pulse is transmitted or an echo is received. The stylus does not make a continuous line on the paper.

The paper used in the recorder is moved horizontally at a constant speed by a paper-feed mechanism. The vertical axis is calibrated in depth. In figure 13-12, D, only one stylus can be seen. However, there are actually two, one on either end of an arm. This arrangement keeps the arm mechanically balanced.

When the recorder switch S306 is on, current which flows through the neon lamp also flows through the stylus and through the paper. The paper is marked alternately, first by one stylus and then by the other. The RECORD-DENSITY CONTROL determines the blackness of the mark on the paper by controlling the amount of current that flows through the stylus. When the recorder switch is off, the stylus is grounded and will not mark the paper.

When the recorder is in operation, the paper moves between the chart feed roll and a contact in series with the CHART-WARNING LAMP I303. When the supply of paper is depleted, the contact drops down on the feed roll. This completes the circuit to the warning lamp and it lights.

The SHOAL-DEEP switch has two positions—one position for sounding in deep water and the other for sounding in shallow water. When the switch is in the SHOAL



position, the depth is read directly from the recorder paper. When the switch is in the DEEP position, a fixed stylus at the bottom of the paper makes a continuous mark. The mark indicates that the depth shown on the paper must be multiplied by five to obtain the actual depth.

The position of the shoal-deep switch determines whether the inside or the outside scale on the dial is read. The inside scale is graduated from 0 to 400 fathoms. The outside scale is graduated from 0 to 2000 fathoms. The signal-interval switch makes it possible to double the maximum depth that can be read from the dial.

The signal-interval switch has two positions. In the 400-2000 position, the driver is keyed once for each revolution of the timing disk. While the switch is in this position, the depth is read directly from the dial. If the switch is set in the 800-4000 position, the driver is keyed once for every two revolutions of the timing disk. The change in the keying interval is accomplished by the half-speed eccentric. In the 800-4000 position, the depth read from the dial must be doubled to obtain the actual depth.

The standard depth cam is mechanically connected to two motors—the SHOAL MOTOR and the DEEP MOTOR. These motors have different speeds. The position of the shoal-deep switch determines which motor is energized. The motor not in use is disconnected from the cam by an overriding clutch mechanism.

When the shoal-deep switch is in the DEEP position, relay K302 operates and changes the contacts used with the cam. The purpose of the cam is to key the driver. To key the driver, two of the three sets of contacts must be closed. If the signal-interval switch is in the 400-2000 fathoms position, relay K301 will be closed. When the contacts associated with the standard depth cam close,

the driver is keyed by grounding the center tap of the oscillator filament transformer through the lead connected to terminal 24.

Relay K301 is controlled by the contacts associated with the half-speed eccentric, when the signal-interval switch is in the 800-4000 position. If the standard depth cam contacts and the eccentric contacts are closed, relay K301 will be closed and the driver is keyed.

Since the eccentric rotates only half as fast as the standard depth cam, the second revolution of the standard depth cam closes its own contacts, but the contacts of the eccentric remain open. Therefore, K301 also will remain open and the driver is not keyed. However, on the next revolution of the standard depth cam, the con-

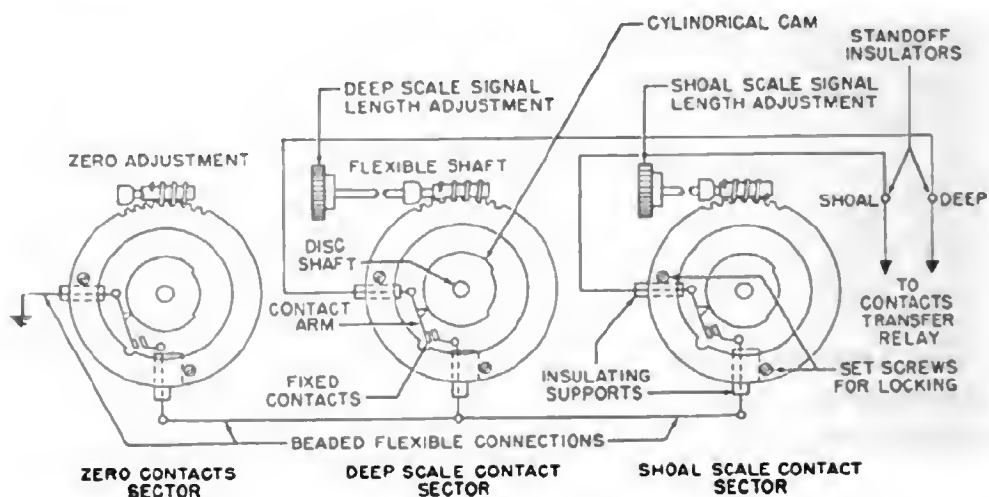


Figure 13-14.—Indicator-contact mechanism.

### Indicator-Contact Mechanism

tacts associated with the standard depth cam and the eccentric are closed and the driver is keyed.

Figure 13-14 is the indicator-contact mechanism. It shows the assembly as having three cams. In the equipment there is actually only one cam and the disks are

stacked together. For ease of explanation the mechanism will be considered as having three cams rotating in synchronism counterclockwise.

The three sets of contacts are fixed to the individual disks. These contacts are the ones associated with the standard depth cam shown in figure 13-13. As the cams rotate, the contacts open and close. When the contacts of the cam at the left close, and the contacts of either of the other two sets are closed, the driver is keyed. The disks may be rotated within limits. This causes the contacts to be rotated with respect to the low surface on the cam.

The zero contacts usually close after the deep contacts and the shoal contacts close. With the disks adjusted as shown in figure 13-14, all three sets of contacts close at the same time. Therefore, the driver is keyed as long as the detents on the contact arms ride on the low surfaces of the cams.

Now consider only the operation of the zero contacts and the deep contacts. Moving the deep contacts clockwise with respect to the cam causes the driver to be keyed for a shorter time. If the deep contacts are rotated clockwise, they will close sooner than the zero contacts. Also, they will open sooner than the zero contacts. The closing of the zero contacts determines the beginning of the driver pulse. The opening of the deep contacts determines the end of the pulse.

The longer the time interval between the closing of the deep contacts and the closing of the zero contacts, the shorter the driver pulse. The same explanation applies to the operation of the shoal contacts. The main advantage of having the zero contacts start the driver is the fact that the zero adjustment does not change when the position of the shoal-deep switch is changed.

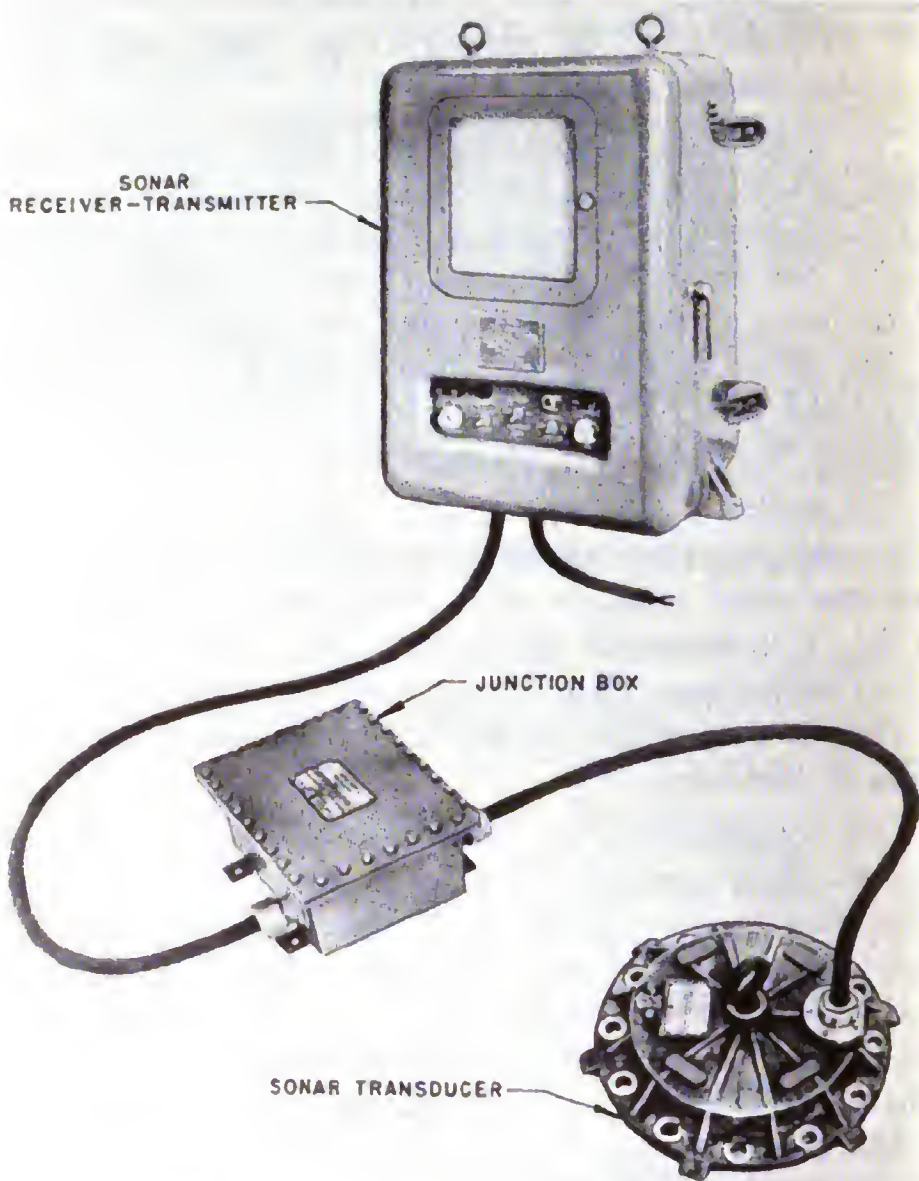


Figure 13-15.—AN UQN-1 sonar sounding set.

### SONAR SOUNDING SET AN UQN-1

Another type of fathometer is shown in figure 13-15. This equipment is quite different from the NMC-2. There is no provision for visual readings other than from the

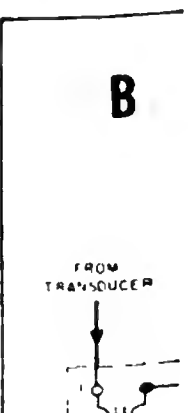
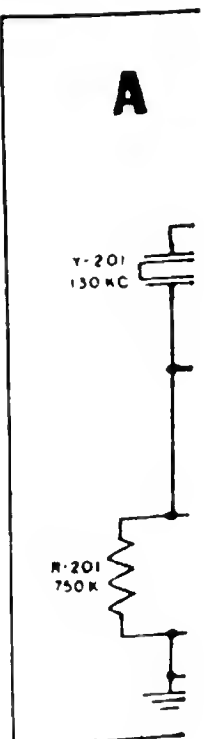


Figure 13-16.—Crystal-controlled oscillators. A, 130-kc and 142-kc ;



recorder. Three ranges are provided: 0-400 feet, 0-400 fathoms, and 0-4000 fathoms.

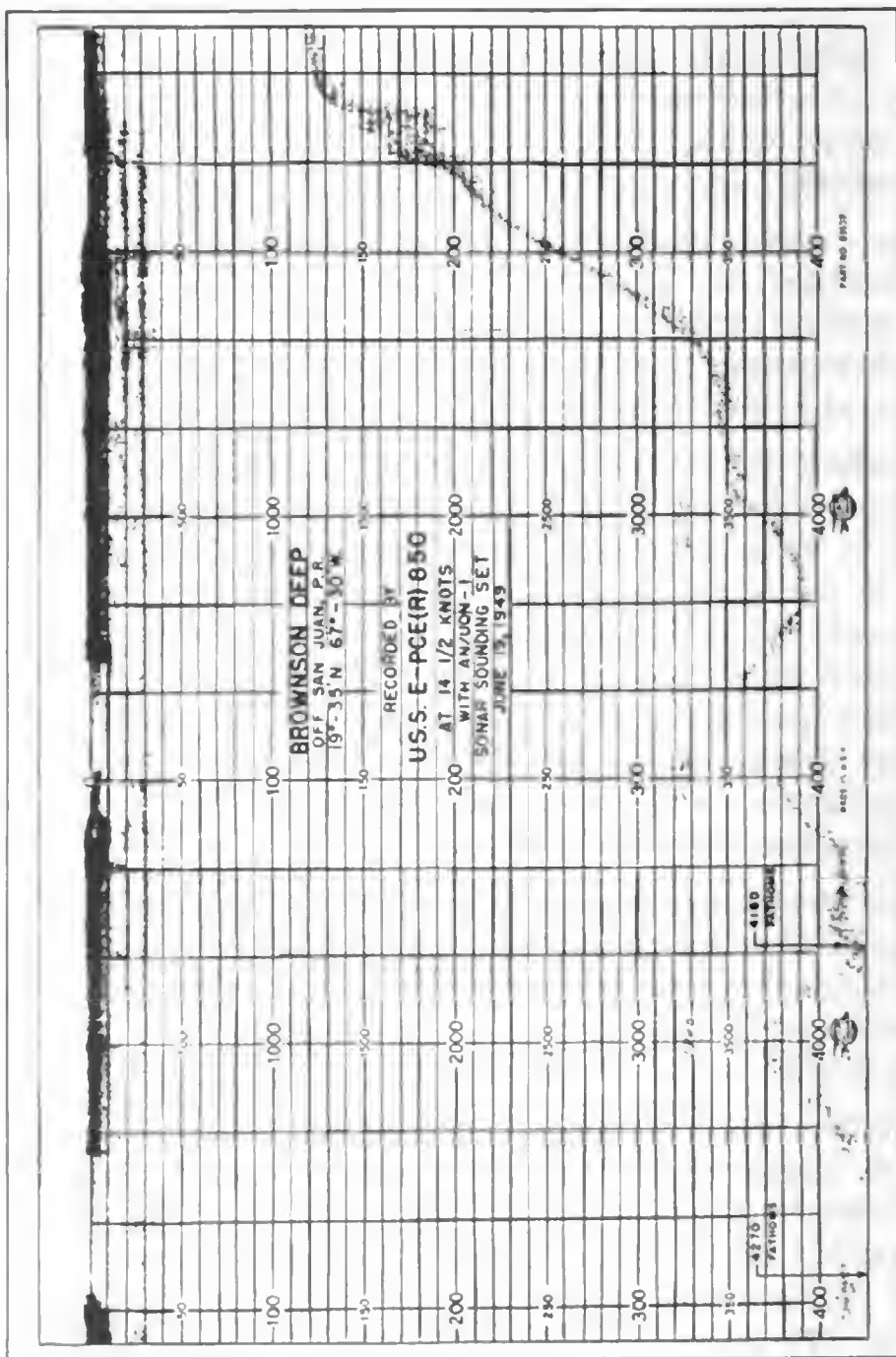
A stylus starts across the recorder chart simultaneously with the transmission of a pulse. The stylus marks the paper twice, once at the top, when the pulse is transmitted, and again, when an echo is received.

The receiver-transmitter contains the receiver, the transmitter, the oscillator, the power supply sections, the recorder, and the control panel. As can be seen from the photograph, this equipment is very compact. The receiver and the transmitter are both crystal-controlled.

A schematic diagram of the crystal-controlled oscillators associated with the transmitter and the receiver appears in figure 13-16, A. The output of the 130-kc oscillator is fed to the mixer tube V202. Some of the components of the 130-kc oscillator form part of another oscillator which has an output of 142 kc. The two frequencies heterodyne in the mixer tube to produce a difference frequency of 12 kc. This output is fed to the transmitter. The driver output, in turn, is fed to the crystal transducer.

A schematic diagram of the receiver is shown in figure 13-16, B. This is a superheterodyne type of receiver. The returning echo has a frequency of 12 kc and is fed to the receiver input. The echo is amplified by V209 and fed to mixer V210.

Another input to the mixer is a 130-kc signal from V201A. These two frequencies heterodyne to produce a difference frequency of 118 kc, which is the i-f frequency. The output of the i-f amplifier V211 is fed to another mixer V212 where it is heterodyned with a signal of 114 kc. The difference frequency is 4 kc. This signal is used to mark the chart. An actual record obtained by using the AN/UQN-1 is shown in figure 13-17.





## QUIZ

1. How may sonar echo-ranging equipment be used for sonar listening equipment?
2. Through what types of media do sound waves travel?
3. What is the equation for relating the velocity of sound to its frequency and wavelength in a given medium?
4. What is the relation between the velocity of sound in air and the temperature of the air?
5. What are reverberations, as applied to sonar?
6. What is attenuation of a sound beam, as applied to sonar?
7. Why does a sound beam usually travel in a curved path instead of a straight path in the ocean?
8. What is a negative temperature gradient?
9. What is an isothermal?
10. What is a bathythermograph?
11. What are the two general types of background noise?
12. Why is listening equipment more useful on a submarine than on a surface vessel?
13. What is magnetostriction?
14. What is the piezoelectric effect?
15. For what purpose is the Doppler effect useful in sonar?
16. Why is the frequency of an echo compared with the frequency of the reverberations instead of being compared with the frequency of the outgoing ping?
17. What is the purpose of a fathometer?
18. During audible sounding with the NMC-2 fathometer how does the operator determine the depth of the water?
19. How is the keying interval of the NMC-2 fathometer changed?
20. How is the transmitted frequency of the AN/UQN-1 sounding set produced?
21. What type of receiver is used in the AN/UQN-1 sounding set?



## **SEARCHLIGHT SONAR SYSTEMS**

### **PRINCIPLES AND OPERATIONAL LIMITATIONS**

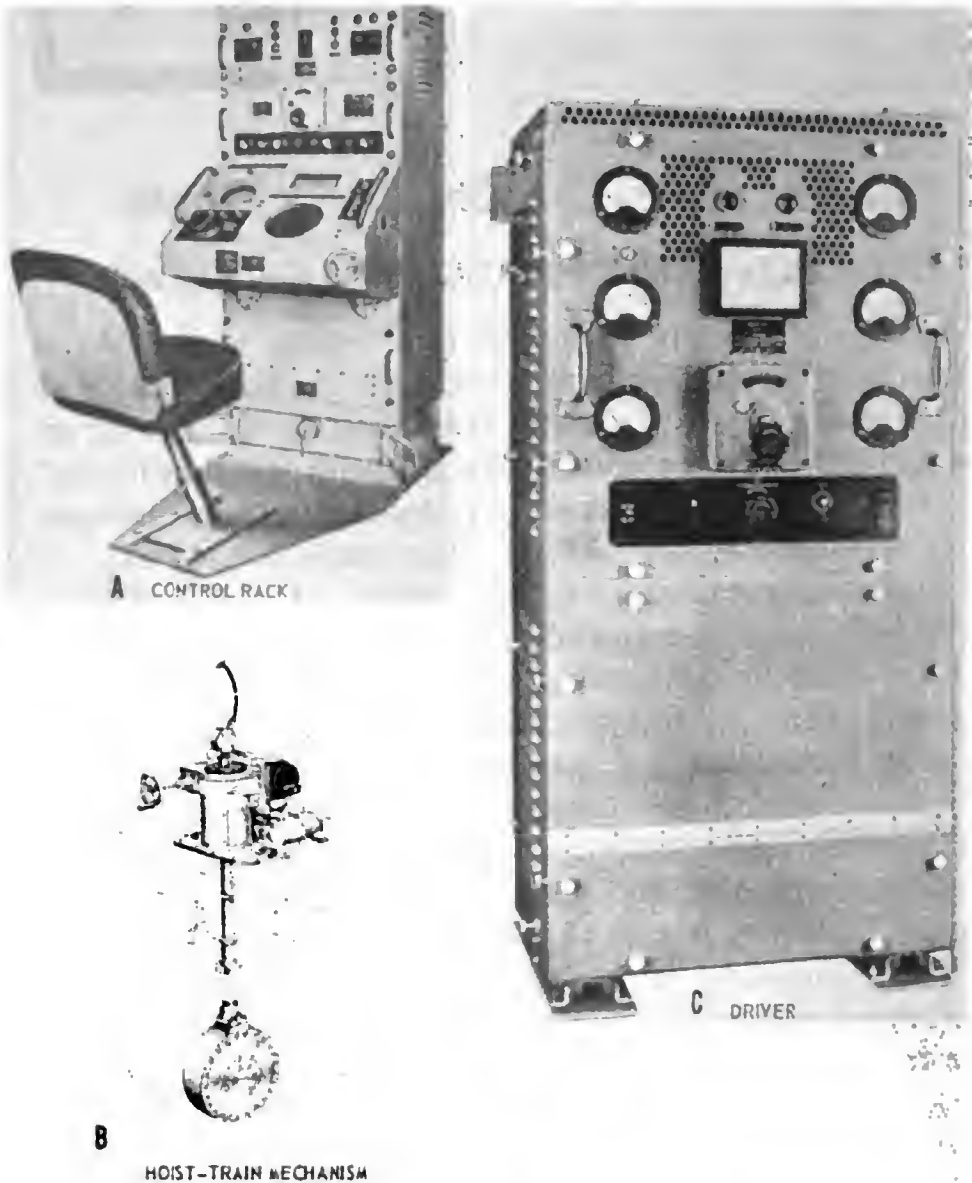
Searchlight sonar is a system in which a directional transducer is used to concentrate the outgoing pulse of sound energy into a narrow beam and to form a directional pattern for receiving. The transducer "illuminates" the target with sound energy in much the same manner that an ordinary searchlight illuminates an object.

A searchlight sonar system consists of a transmitter, a receiver, and a transducer. The searchlight system is widely used in detecting underwater targets. A transducer is connected to a transmitter output during the time a pulse is transmitted. At the end of the pulse, a relay or other device disconnects the transducer from the transmitter and connects it to the receiver input. After a given interval of time, the transducer is again connected to the transmitter and the cycle is repeated.

The transducer in a searchlight system concentrates the sound energy into a beam. The receiving pattern and the transmitting pattern are the same. The bearing of a target is determined by training the transducer for maximum echo strength.

The directivity of the transducer determines the accuracy of the bearing information. The sound beam for a given frequency can be made narrower in azimuth by increasing the width of the transducer diaphragm. If a

higher operating frequency is used, the transducer can be made smaller and still have the desired directivity. However, if the frequency is increased too much, propa-



**Figure 14-1.—QGB sonar equipment.**

gation losses caused by absorption become objectionable. One of the disadvantages of the searchlight system is

the long time it requires to search the area around a vessel. The ping-listen-train search is a slow process. Also, the ranges obtained are slant ranges, whereas in attacking a submarine the horizontal range is needed to compute the range for firing the forward throwing weapons and the position for dropping depth charges.

## **QGB SEARCHLIGHT SONAR**

The QGB sonar equipment was designed for installation in destroyer escort vessels. A photograph of the QGB is shown in figure 14-1. This equipment uses a magnetostriction transducer. When changing the operating frequency of the equipment, the transducer also must be changed if the equipment is to operate efficiently. Transducers having resonant frequencies of 20, 22, 24, and 26 kc are available. The receiver is tunable between 17 and 26 kc.

The hoist-train mechanism is mounted in a sea chest. The transducer and dome may be raised from and lowered into the water. When they are hoisted into the sea chest, the dome seals off the chest and allows the technician to service the transducer from inside the ship.

### **Keying Unit**

The keying unit has four functions depending on the position of the RANGE SELECTOR switch. The operation of the keying unit with the range selector in its various positions is as follows: (1) SEARCH position—the keying unit provides keying pulses to actuate the bearing deviation indicator (BDI) sweep relay and the driver keying relay. The latter relay automatically times the period that these two relays are closed and the interval between their operating periods; (2) RECORDER position—the keying unit acts as a switch to start the travel of the indicator range recorder stylus, provides pulses for operating the

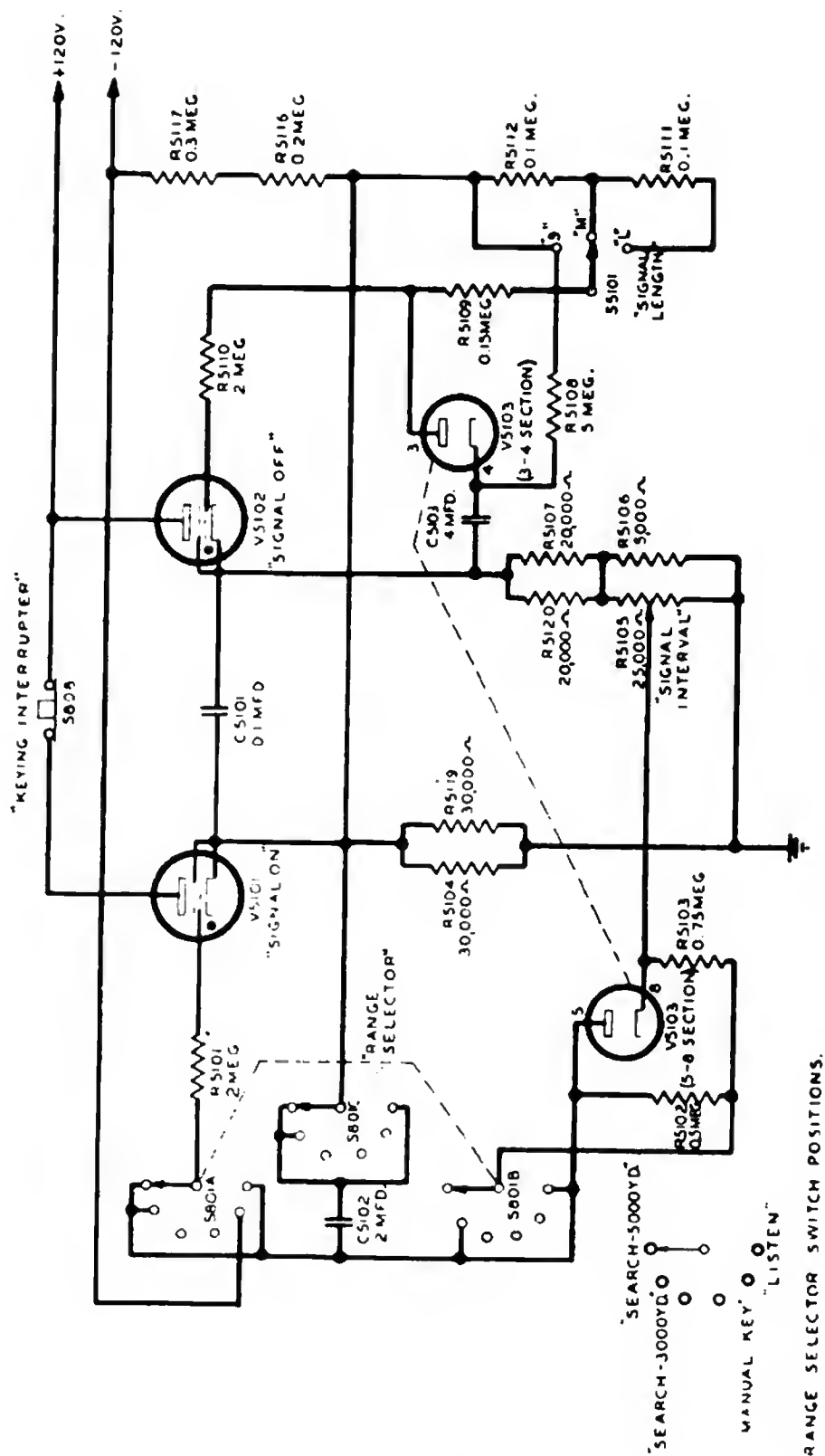


Figure 14-2.—Simplified schematic diagram of the keying unit.

BDI sweep relay and the driver keying relay, and determines the keying pulse duration (signal length); (3) LISTEN position—the operation is the same as in the search position except that the driver keying relay is disconnected; and (4) MANUAL-KEY position—the keying unit is biased beyond cut-off so that it is totally inoperative. The equipment is keyed by closing the hand key on the training control unit or by closing the test key.

A simplified schematic diagram of the keying unit is shown in figure 14-2. Assume that the SIGNAL-ON tube is conducting and the SIGNAL-OFF tube is non-conducting due to a negative bias voltage on its grid. The bias is obtained from the charge on capacitor C5103. The charging path for C5103 is through V5102 (when it was conducting), through the power supply, to ground, through R5104 and R5119 in parallel, and through R5108.

The bias voltage from the capacitor is applied to the grid of V5102 through R5108, through S5101 and its associated resistors, through R5109 and R5110. While the signal-on tube is conducting, capacitor C5101 charges. Its charging path is through V5101, through the power supply, to ground, and through the cathode resistors of V5102. The charge on capacitor C5103 (received when V5102 was conducting) places the cathode of V5102 at +120 volts above ground.

Capacitor C5103 discharges when V5101 is conducting through diode V5103 (pins 3 and 4), resistor R5109, switch S5101 and its associated resistors, tube V5101, the power supply, to ground, and through the series-parallel resistor network in the cathode circuit of V5102. With V5101 conducting the voltage drop across its cathode resistors causes the diode (V5103 pins 3 and 4) to conduct. The rate at which capacitor C5103 discharges may be varied by changing the position of the SIGNAL LENGTH switch. When capacitor C5103 discharges sufficiently, the signal-off tube conducts.

The instant the signal-off tube begins to conduct, the voltage drop across its cathode resistors adds to the +120 volts across capacitor C5101. The result is that the cathode of the signal-on tube becomes +240 volts momentarily. The plate voltage is only +120 volts; therefore, the tube stops conducting. At the time the signal-off tube starts conducting, capacitor C5103 starts to charge again.

When the signal-on tube is conducting and the signal-off tube is nonconducting, another capacitor C5102 also is charged by the cathode voltage of the signal-on tube. The charging path for this capacitor is through S801C, V5101, and the power supply to ground and through resistor R5105 and the diode V5103 (pins 5 and 8). The diode conducts only when the capacitor is charged. The purpose of the diode is to provide a short charging time and a long discharge time for the capacitor. As mentioned previously, the signal-on tube stops conducting when the +240 volts is momentarily applied to its cathode. But, if the grid is not made negative, the tube will conduct as soon as this voltage is removed from the cathode. The negative potential on the grid is obtained from the charge on capacitor C5102. The length of time that the signal-on tube is cut off depends on the discharge time of the capacitor and can be adjusted with the SIGNAL-INTERVAL control R5105.

The signal-on tube conducts again when capacitor C5102 discharges. When this tube conducts, its cathode voltage is +120 volts. This voltage adds to the 120 volts across C5101 which was established while V5102 was conducting and the cathode of the signal-off tube momentarily has a potential of +240 volts placed on it cutting the tube off in the same manner V5101 was previously cut off. Capacitor C5101 loses its charge quickly and V5102 would conduct almost immediately, if it were not for the negative voltage placed on its grid by capacitor C5103. When the range selector switch is in the MANUAL



**KEY** position, a fixed negative voltage is applied to the grid of the signal-on tube. Keying is accomplished by pressing the hand key.

### Keyer Tube

A simplified schematic diagram of the keyer tube is shown in figure 14-3. The BDI sweep relay K701 and the driver keying relay K105 are energized by the keyer tube. This is true for all positions of the range selector switch except the manual key position. The coil of K701 is connected between the plate of the keyer tube and the +120-volt bus. It is in parallel with the driver keying relay coil, when the range selector switch is in any position except LISTEN.

During the signal-off period the control grid is supplied with -60 volts from a voltage divider across the -120 volt bus. During the signal-off period the keying tube is cut off. Therefore, no current is drawn through the relay coils and the relays are inoperative.

When the signal-on tube conducts, its cathode voltage is raised to about +120 volts. This voltage cancels the bias on the keyer tube. The keyer tube conducts and current flows through the coils of relays K701 and K105.

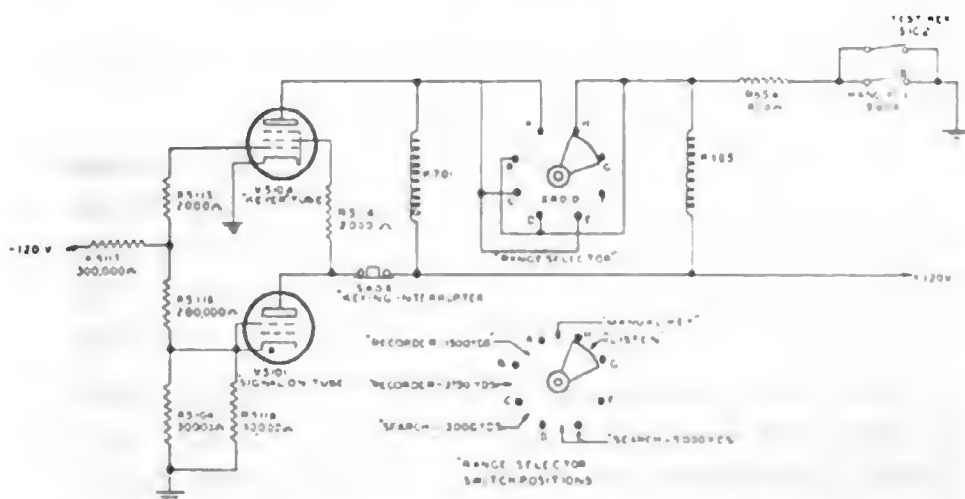


Figure 14-3.—Simplified schematic diagram of the keyer tube.

The keyer tube conducts for the same length of time as the signal-on tube. When the signal-on tube stops conducting, the keyer tube bias is restored and the keyer tube is cut off until the signal-on tube again conducts. The keying interrupter is necessary because, when the equipment is first turned ON, the signal-on and the signal-off tubes may be conducting at the same time. Pressing the keying interrupter removes plate voltage from the signal-on tube and allows the signal-off tube to assume control.

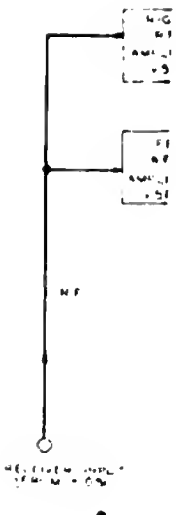
### Driver Unit

A complete block diagram of the QGB sonar is shown in figure 14-4. The driver unit is composed of a master oscillator and a push-pull power amplifier. A simplified schematic diagram of the driver unit is shown in figure 14-5. The output power of the driver is 400 watts. The driver is tunable between 17 and 27 kc.

When relay K109 is in the position shown in the diagram, the frequency determining components of the master oscillator are the variometer L101 and capacitor C122. The output of the oscillator is capacity coupled to the power amplifier. The power amplifier is coupled to the transducer by transformer T102. The oscillator and power amplifier are biased below cutoff by fixed bias from a voltage divider.

The oscillator is keyed by relay K105. The contacts of this relay short-out the cutoff bias on the tube. When the oscillator is keyed, the input to the receiver is shorted, the transducer is connected to the output of the driver, and cutoff bias is removed from the master oscillator.

Under some operating conditions it may be desirable to sweep the frequency of the master oscillator in order to give the echoes a more easily distinguished tone. This is done with a motor-driven capacitor. A schematic dia-



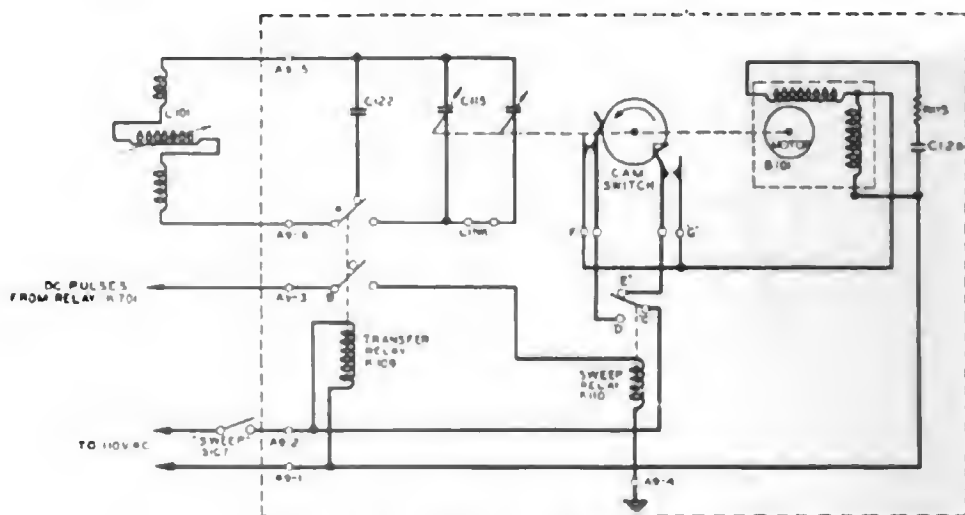
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Figure 14-4.—Block diagram of the





A cam-operated switch is mounted on the end plate of the variable capacitor. The cam is attached to the capacitor shaft and rotates as the rotor plates turn. This cam actuates two switches which complete the a-c circuit to the motor. The purpose of these switches is to keep the motor energized until the capacitor has rotated one complete revolution. This allows the plates to be in the FULLY MESHED position at the beginning of the next revolution. The capacitor rotates from the maximum to the minimum



capacity position in such a way that these positions coincide with the start and finish of each oscillator pulse.

The receiver in the QGB has two channels—the audible channel and the visual (BDI) channel. The audible chan-

nel output is fed to the loudspeaker and to the range recorder when it is operating. The visual channel output energizes the horizontal deflection circuits and the brightening circuits in the BDI.

The BDI aids the operator in training the transducer exactly on the target. The operating principle of the BDI is shown in figure 14-7,A. The transducer is split electrically into two sections. When the transducer is trained exactly on the target, the amplitude and phase of the signals induced into each half of the transducer are the same and there is no deflection of the BDI trace. When the transducer is trained either to the right or to the left of the target, the amplitude of the signal induced into the left half of the transducer is equal to the amplitude of the signal induced into the right half of the transducer. However, there is a phase difference between the two signals. The presentation on the BDI scope is similar to that shown in figure 14-7,B.

**BDI CHANNEL.**—In the BDI (visual) channel of the receiver the phase difference between the two signals is changed to an amplitude difference which is applied as deflection voltage to a cathode-ray tube. Refer to figure 14-4. The output of the two transducer halves is fed to separate amplifiers.

The outputs of the two r-f amplifiers are applied to the grids of the left and right BDI channel converter tubes. The two grids are connected through a phase-shifting network which gives approximately an  $80^\circ$  phase shift. The electrical center of the phase-shifting network is connected to the audible channel r-f converter tube V516. The output of the converter oscillator V513 is coupled to the grids of the three r-f converter tubes through isolation resistors.

The  $80^\circ$  phase-shifting network converts the phase difference between the signals from the left half and the right half of the transducer into an amplitude difference.

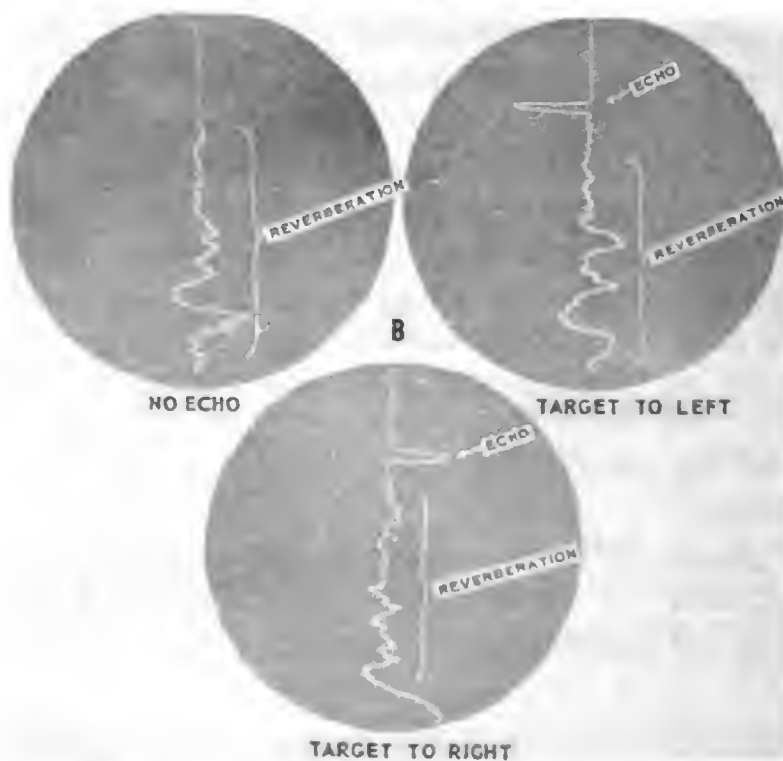
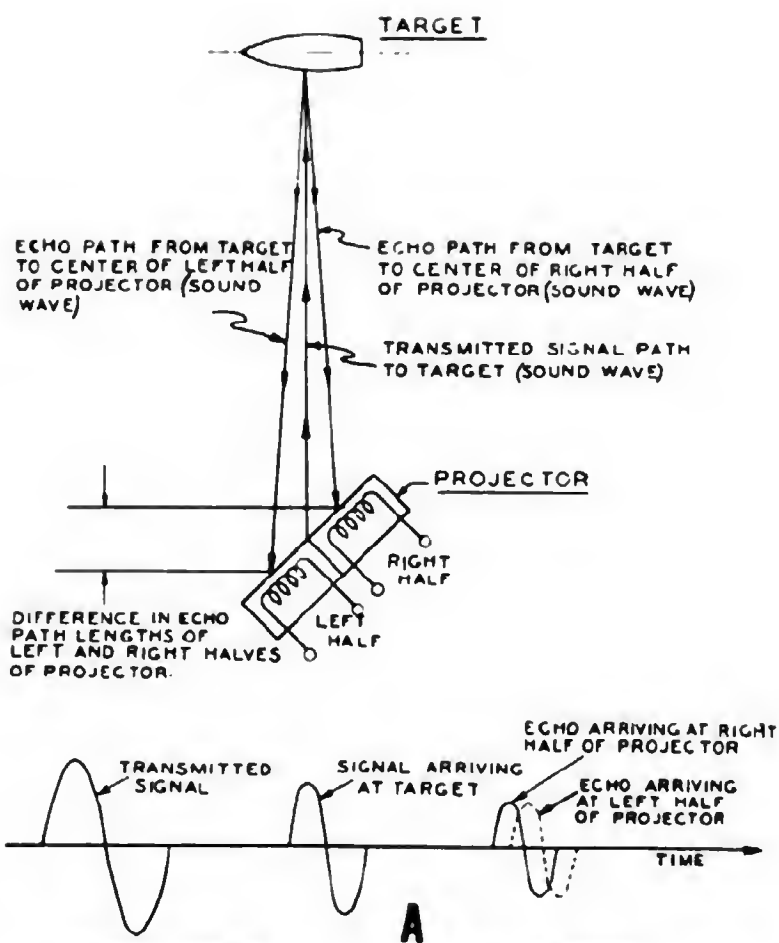
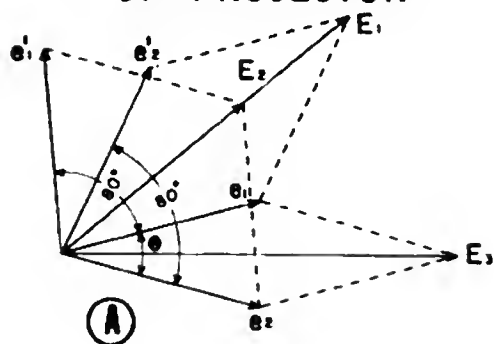


Figure 14-7.—Bearing deviation indicator.



## TARGET TO LEFT OF PROJECTOR

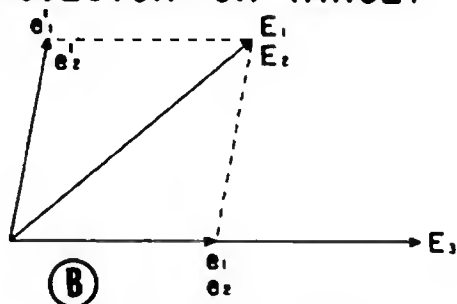


$\theta$  = DIFFERENCE IN PHASE OF SIGNALS  
AT OUTPUT OF PROJECTOR HALVES

$e_1$  = OUTPUT FROM LEFT HALF OF  
PROJECTOR

$e_2$  = OUTPUT FROM RIGHT HALF OF  
PROJECTOR

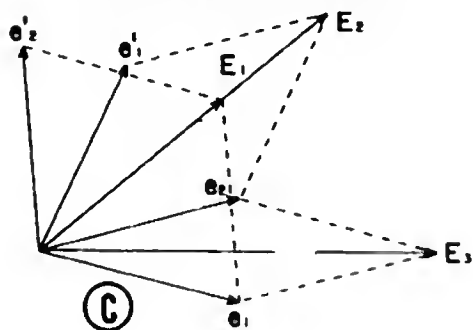
## PROJECTOR ON TARGET



$e_1' = e_1$  SHIFTED 90 DEGREES BY LEAD  
LINE

$e_2' = e_2$  SHIFTED 90 DEGREES BY LEAD  
LINE

## TARGET TO RIGHT OF PROJECTOR



$E_1$  = RESULTANT VOLTAGE ON CONTROL GRID  
OF LEFT CONVERTER TUBE V502

$E_2$  = RESULTANT VOLTAGE ON CONTROL GRID  
OF RIGHT CONVERTER TUBE V512

$E_3$  = VOLTAGE APPLIED TO AUDIBLE CHANNEL  
FROM CENTER OF LEAD LINE

Figure 14-8.—Vector diagram showing the effect of the  
phase-shifting network.

This difference is applied to the grids of the left and right BDI channel r-f converter tubes.

The left r-f converter tube receives the amplified output of the left half of the transducer. In addition, it also receives the amplified output of the right half of the transducer, the phase of which has been shifted  $80^\circ$  leading by the phase-shifting network. The right r-f converter tube receives the amplified output of the right half of the transducer, and in addition, the amplified output of the left half of the transducer which has been shifted by the phase-shifting network  $80^\circ$  leading.

A vector diagram of these voltages is shown in figure 14-8. The vector diagram shows the three possible situations that can occur. Figure 14-8,A, the voltage applied to the grid of the left converter tube is greater than that applied to the right converter tube. The situation is reversed in figure 14-8,C. When the transducer is trained exactly on the target (figure 14-8,B), the voltages applied to the two grids are the same. This satisfies the condition of changing the phase difference into an amplitude difference.

The output of the converter oscillator is fed to the grids of the left and right BDI converter tubes where the input signal from the target is heterodyned to the i-f frequency. A 600-cycle switching voltage is applied in push-pull to the screen grids of these converter tubes. The switching voltage has sufficient amplitude to cut off the tubes when the 600-cycle signal is on its negative alternation. Only one tube will be cut off at any one time, since the 600-cycle signal is applied in push-pull.

Figure 14-9 shows the waveforms in the receiver. The output of the r-f converter tubes is amplified by two i-f amplifier stages and applied to detector V505. The output of the detector is the envelope of the i-f signal. The detector output goes through one stage of audio amplification and then to a phase-sensitive detector.

# Signal I Pr

BDI SWITCHING  
(800 CYCLES).

RF SIGNAL TO F  
VERTER TUBE

RIGHT BDI CH  
VOLTAGE FROM  
VS06 (800 CYC

CONVERSION C  
RF CONVERTER

OUTPUT OF R1  
TUBE VS12 (80

RF SIGNAL TO  
TER TUBE VS0

LEFT BDI CH  
TING VOLTAGE  
LATOR VS08

CONVERSION I  
CONVERTER 1

OUTPUT OF L  
TER TUBE V

COMBINED OR  
CHANNEL RF  
(80 KC), E P

OUTPUT OF B  
VS05 (AUDIO)

SIGNAL TO B  
VS06 (AUDIO)

OUTPUT OF I  
AMPLIFIER VS

PULSE FROM  
TO CONTROL I  
DETECTOR VS

GAIN OF PHA  
DUE TO APPLI

OUTPUT OF I  
VS10 DUE TO

Figure 14-9.—Receiver wav.

Equal Si



The output of the switching oscillator also is fed to the grid of the phase sensitive detector. A limiter tube, one section of V509, removes the positive alternations of this voltage so that only the negative alternations are applied to the grid of the phase-sensitive detector. The negative alternations are great enough to cut off the phase-sensitive detector. This places the detector in an OFF condition for one-half the time at a 600-cycle rate. The off time coincides with the negative alternations of the switching oscillator voltage.

The phase-sensitive detector amplifies only during the time that the switching voltage is positive. The output of the phase-sensitive detector is a series of positive 600-cycle pulses, if the signal to the grid of the right r-f converter tube is greater than that applied to the left r-f converter tube. The output of the phase-sensitive detector is a series of 600-cycle negative pulses, if the signal to the left r-f converter tube is greater than that applied to the right r-f converter tube. If the inputs to the r-f converters are equal, the output of the phase-sensitive detector is zero.

The phase-sensitive detector output is fed to the horizontal deflection amplifier V703. The horizontal deflection coils of the magnetically deflected cathode-ray tube are connected in the cathode circuit of this amplifier. The deflection coils therefore receive the same pulses that appear in the output of the phase-sensitive detector.

The coils have self inductance which resists the voltage change caused by the pulses. If only a single pulse is applied to the deflection coils, the change in current through them is negligible. However, a series of pulses causes the current to gradually increase to a value corresponding to the average amplitude of the pulses. If the pulses are negative, the electron beam of the cathode-ray tube is deflected to the left. If the pulses are positive, the deflection is to the right. The direction of the deflection

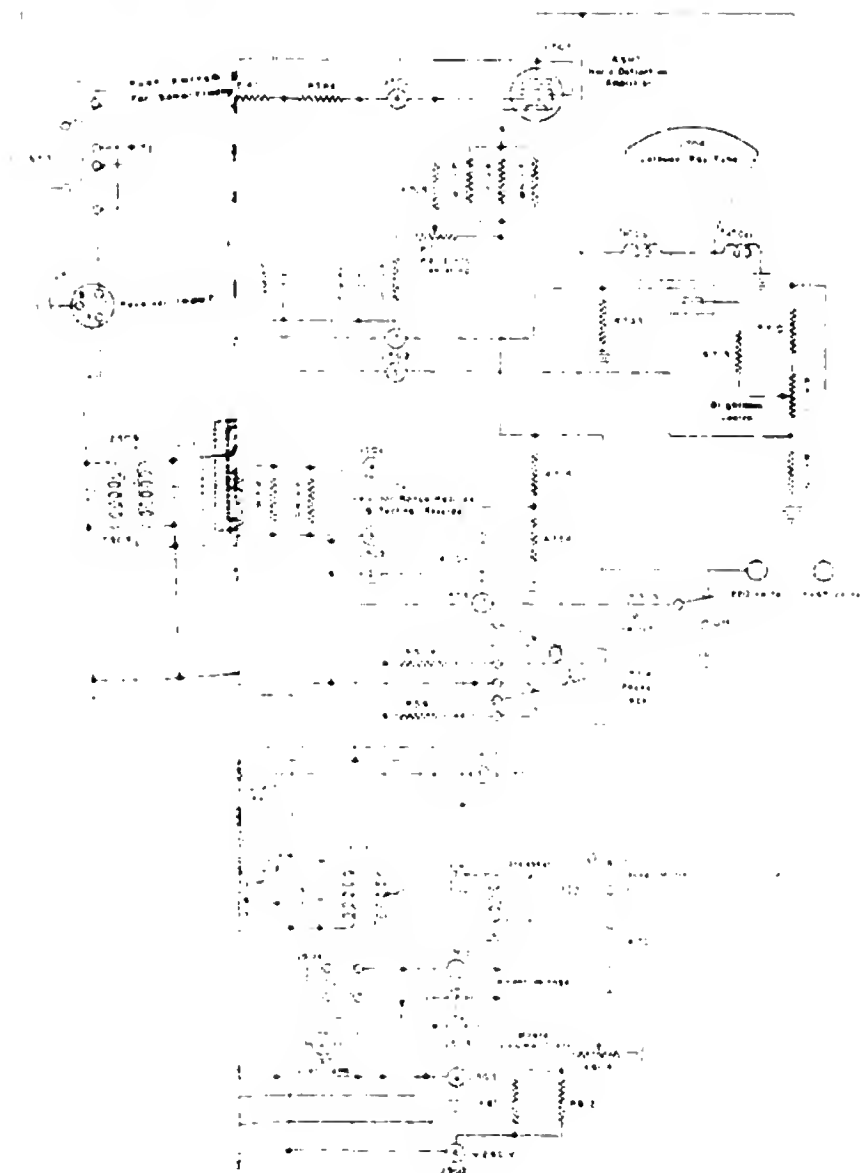
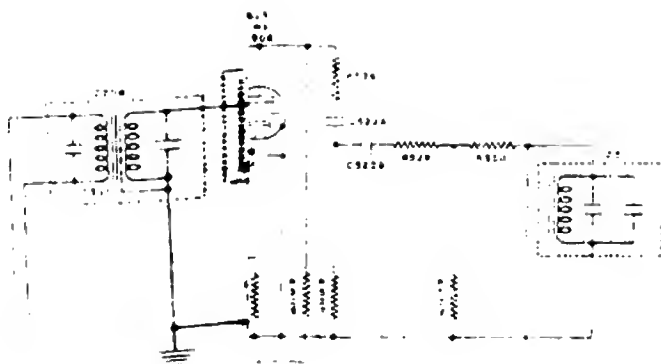
tells the operator in which direction to train the transducer to bring it on target.

The vertical deflection amplifier produces a saw-tooth current. It flows through the vertical deflection coils and produces the vertical sweep of the electron beam. The sweep starts at the bottom of the cathode-ray tube at the instant the driver is keyed and progresses up the face of the tube as the transmitted pulse moves out through the water. A range indication may be obtained from the BDI by noting the position on the sweep where the echo appears. However, the range is usually obtained from the range recorder.

**AUDIBLE CHANNEL.**—The audible channel of the receiver supplies outputs which are fed to the loudspeaker and the range recorder. A schematic diagram of the receiver is shown in figure 14-10. The input to the audible channel is taken from the junction of resistors R592 and R593 through capacitor C527. The incoming signal is heterodyned to the i-f frequency in the r-f converter tube V516. One stage of i-f amplification follows the converter.

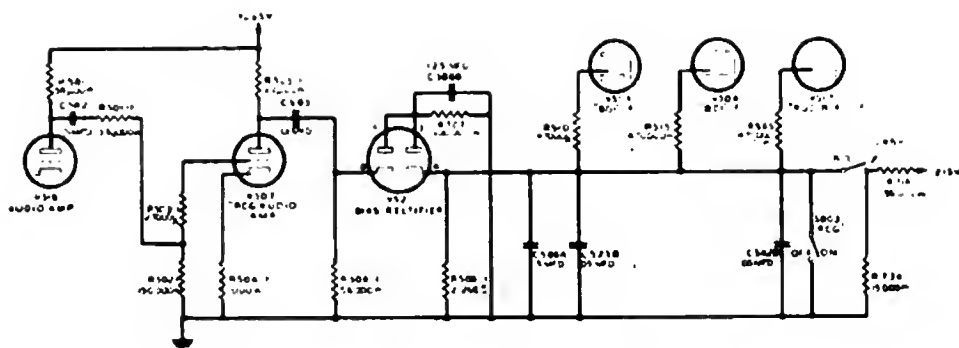
The output of the i-f amplifier tube is applied to the control grid of the second detector and an output of the BFO is applied to the screen grid of the second detector. The two signals beat together and the output is an audio signal. Audio amplifier V519 has three outputs. One output is supplied to the audio output tube which drives the loudspeaker. The second output goes to the recorder output amplifier which excites the stylus of the range recorder. The third output is applied to the RCG (reverberation controlled gain) amplifier.

A simplified schematic diagram of the RCG circuit is shown in figure 14-11. When the RCG switch is ON, the parallel capacitors C542B, C523B, and C589A are charged up to -46 volts during the time that relay K701 is closed. The negative ends of the capacitors are connected to the cathode pin 4 of diode V521 (pins 3 and 4).









**Figure 14-11.—Simplified schematic diagram of the RCG circuit.**

If no signals enter the receiver, the diode conducts immediately after K701 opens and the capacitors discharge rapidly. In this case no negative voltage from the capacitors is applied to the i-f amplifiers. When signals enter the receiver in the form of reverberations, they go through the audible channel and are fed to the RCG amplifier. The output of this tube is applied to the other half of V521. The voltage drop across R507-1 also is applied to the plate of the discharge diode.

As long as the voltage on the plates of the diodes is more than  $-46$  volts, the diodes cannot conduct and the only discharge path for the parallel capacitors is a slow discharge path through resistor R508-1. The voltage drop across R508-1 is such that it reduces the gain of the i-f amplifiers while the reverberations are high. As the reverberations decrease, the discharge diode (pins 3 and 4) conducts, discharging the parallel capacitors rapidly and restoring the gain of the i-f amplifiers to normal.

## Indicator Range Recorder

The range recorder provides a means of accurately indicating the range of a target. The range indications appear in a manner similar to that on the NMC-2 fathom-

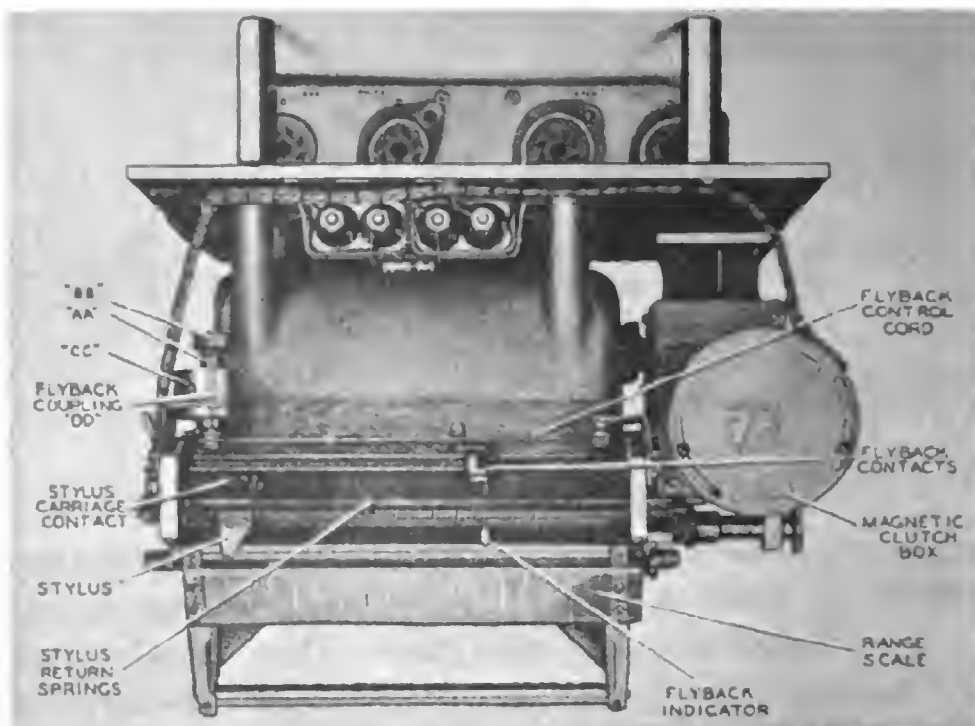


Figure 14-12.—Range recorder unit of the QGB sonar.

eter. The recorder paper travels under a calibrated scale. When an echo is received, current flows from the stylus through the paper to ground.

The passage through the paper causes a chemical reaction which produces a mark to indicate the range. The range is read from the scale. The recorder operates only when the range selector switch is in either the 1500- or the 3750-yard position. A photograph of the range recorder removed from the bridge control rack is shown in figure 14-12.

The recording stylus is mounted on a carriage which slides freely on two guide bars. The carriage is drawn from left to right by a cord wound on a pulley. The pulley is rotated by a magnetic clutch, which is energized through slip rings and is driven through gears by a synchronous motor.

The same motor actuates the paper drive mechanism.

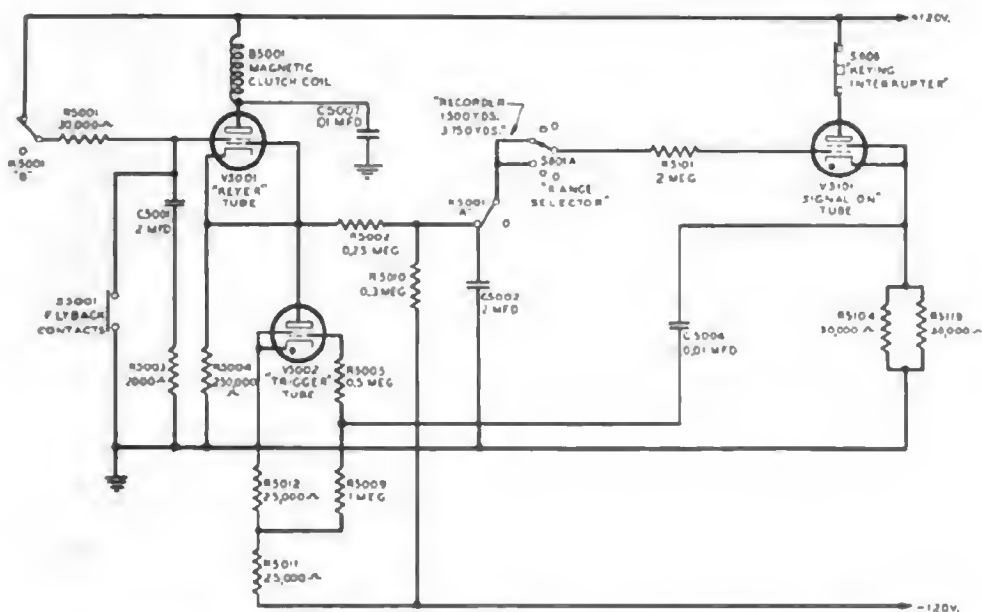


Figure 14-13.—Simplified schematic diagram of the magnetic clutch circuit.

During the time that the stylus carriage is moving to the right side, it compresses two helical springs. The springs return the carriage rapidly to its starting position at the left side of the recorder when the magnetic clutch is deenergized. The synchronous motor runs continuously, but the stylus carriage moves only when the clutch is energized.

A flyback contact, located on two guide bars in back of the guide bars for the stylus carriage, causes the magnetic clutch to be deenergized, when the stylus moves to the right. Deenergizing the magnetic clutch allows the stylus to fly back to its starting position at the left side.

**OPERATION OF THE MAGNETIC CLUTCH.**—Circuits in the keying unit energize the magnetic clutch. A simplified schematic diagram of the clutch coil circuit is shown in figure 14-13. When the signal-on tube fires, there is a large voltage drop across its cathode resistors.

At the first instant that the signal-on tube fires, capacitor C5004 appears as a short circuit and a large posi-

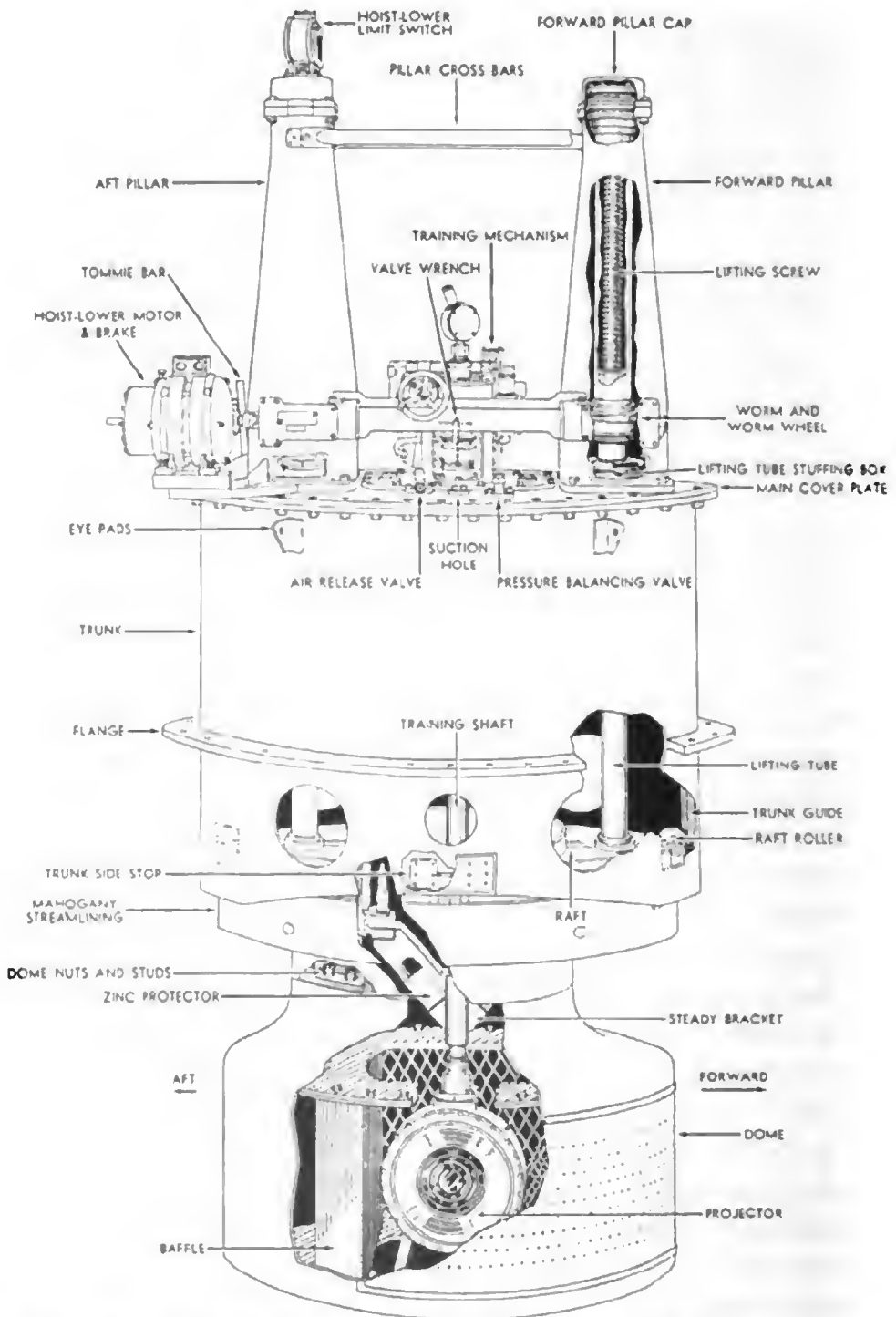


Figure 14-14.—Dome and retracting-gear assembly of the QGB sonar.



shaped to minimize turbulence around the transducer when the vessel is under way and thereby reduces interference with the sound energy. The dome is free-flooding when it is lowered.

The trunk and the main cover plate form a compartment to house the dome, when it is in its retracted position. They also support the hoist-lower and training mechanisms. A raft carrying the dome is hoisted and lowered by the lifting tubes.

In its lowered position the raft rests on the trunk stops. The transducer and training shafts are supported by the raft only when the transducer is being raised or lowered. When the dome is housed, the raft forms a watertight seal with the main cover plate.

The dome may be hoisted or lowered either from the training-control unit or from the location of the retracting assembly. A schematic diagram of the hoist-lower circuit is shown in figure 14-15. If the electrical circuits for the hoist-lower mechanism should fail, the dome may be positioned by using the handwheel.

If the BRAKE RELEASE switch on the dome seating control unit is on, pressing either the LOWER switch on the dome seating control unit or the HOIST-LOWER switch energizes relay K1603 and closes its normally open contacts. This provides a complete circuit through the coil of K1601. The contacts of K1601 then release the hoist-lower motor brake by connecting 3-phase power to the brake coil. As soon as the dome has started to lower, the upper brake limit switch closes and K1601 is kept energized regardless of the position of relay K1603.

Closing the lower switch also energizes coil L of the hoist-motor controller. This closes contactor L which connects 3-phase power to the hoist-lower motor. At the same time the holding contact L1, in parallel with the lower button, closes and keeps coil L energized after the lower button is released. The hoist-lower motor operates until

the dome reaches the lower limit switch. When this switch opens it breaks the circuit to relay K1603 and to the controller coil L, but does not open relay K1601 because the brake limit switches are still closed. Relay K1601 remains energized and the brake remains off until further travel or coasting of the dome opens the lower brake limit switch. This deenergizes the brake coil allowing the brake to be applied to the hoist-lower motor.

The dome is seated in the lowered position by hand because coasting does not always seat it securely. The brake release switch must be turned off before hand seating is attempted.

With the brake release switch in the ON position, pressing the hoist switch energizes coil H of the motor controller and relay K1602. This relay completes the circuit to relay K1601, which energizes the brake coil just as it does in the lowering process. Closing contactor H applies 3-phase power to the hoist-lower motor in the proper phase to reverse the motor. At the same time contact H1 parallels the hoist button and keeps coil H and relay K1602 energized after the hoist button is released.

Hoisting of the dome continues until it reaches the up-limit switch. When this switch is opened, the circuit to relay K1602 and to coil H is broken. Relay K1601 does not open because the brake limit switches are still closed. Relay K1601 remains energized and the brake remains off until further travel or coasting of the dome opens the upper brake limit switch. This deenergizes the brake coils allowing the brake to be applied to the hoist-lower motor. Pressing the EMERGENCY STOP button deenergizes all the relays by removing power from the brake coil and the hoist-lower motor.

Relay K1604 protects the hoist-lower mechanism in case one of the contactors should stick. If the lower limit switch opens during the lowering operations, but contactor L sticks, the hoist-lower motor will continue to run

after it should have stopped. When the brake limit switch opens, relay K1601 is deenergized allowing the brake to operate and to deenergize relay K1604. The contacts of K1604 then close and current flows through the normally closed contacts of K1603 and the normally open (but closed due to sticking) contact of L to coil H of the motor controller.

Contactor H is interlocked mechanically with contactor L to prevent both from being closed at the same time. With this arrangement coil H, when energized, has sufficient energy to open the contacts of coil L. When the contacts of coil L are forced open by coil H, the hoist-lower motor reverses just as though the hoist button had been pressed. This reverses the travel of the mechanism causing it to move downward. If the contacts of coil H stick, a similar action takes place at the upper limit of travel.

The coils of overload relays 20L and 10L (not shown in the diagram) are in series with two phases of the motor. These relays protect the hoist-lower motor and are reset manually by pressing a button on the front of the hoist-lower motor controller unit.



## QUIZ

1. What is a searchlight sonar system?
2. What basic units make up a searchlight sonar system?
3. During what time in the cycle of operation is the transmitter connected to the transducer?
4. At the end of each transmitted pulse how is an echo picked up?
5. How is the bearing of a target determined with a searchlight sonar?
6. What is the nature of the receiving pattern as compared to the transmitting pattern?
7. What determines the accuracy of the bearing information of a searchlight sonar system?
8. What is the chief disadvantage of a searchlight system?
9. How are the transducer and dome of the QGB raised from and lowered into the water?
10. In QGB equipment, why is the keying interrupter in the plate circuit of the signal-on tube necessary?
11. How is the oscillator in the driver unit of the QGB keyed?
12. What is the purpose of a BDI?
13. When are the outputs of the phase-sensitive detector equal in the QGB?
14. How can a range indication be obtained from BDI?
15. To what is the output of the audible channel of the QGB receiver fed?
16. In the range recorder unit of the QGB when does the stylus carriage move?
17. How is the magnetic clutch of the range recorder in the QGB energized?
18. What is the purpose of the dome surrounding the transducer in the QGB?
19. What precaution must be taken before hand seating of the dome of the QGB is attempted?
20. How does pressing the emergency stop button deenergize all the relays in the QGB hoist-train mechanism and stop the hoist-lower motor?



## **SONAR AND LISTENING EQUIPMENT**

### **GENERAL DESCRIPTION OF SCANNING SONAR**

All searchlight systems of echo ranging involve a short transmission of sound energy followed by a longer period during which the sonar operator is alert for echoes. Because of the limited sector covered by the relatively narrow sound beam and the time consumed between transmissions, searchlight sonar proved to be very unsatisfactory in locating underwater targets. The necessity for rapidly searching a wide area led to the development of scanning sonar.

The scanning sonar system is much more flexible than the searchlight system. Scanning sonar equipment is, in effect, a combination of two types of ultrasonic echo ranging and listening equipment operating simultaneously. One provides a continuous visual display of acoustic reception from all directions and the other provides audio response from any desired single direction. The latter is the exact equivalent of searchlight sonar.

In scanning sonar the transducer is composed of a large number of small magnetostriction units arranged in a circle. They are connected in parallel during transmitting and project sound energy in all directions. Each transducer unit is connected to its own preamplifier for re-

ceiving the returning echo. The outputs of the preamplifiers are connected to a rotary switch which scans the outputs of the individual units. After passing through the receiver these signals are applied to a cathode-ray tube. The visual presentation is similar to a PPI presentation in radar.

## **QHB-a SCANNING SONAR**

The QHB-a scanning sonar equipment is a QHB equipment modified to provide certain operating features required for application as part of the integrated attack sonar system. The original QHB equipment was converted to QHB-a by a modification kit. Current equipment is modified at the factory and no field conversion is necessary. A pictorial diagram of the QHB-a system is shown in figure 15-1.

### **Transducer**

The transducer converts the electrical energy from the transmitter into sound energy and the returning echo into electrical energy. It is composed of two electrically independent transducers in the same housing. The principal element consists of 48 independent vertical transducers arranged in a circle. The transducers are the magnetostriction type and use permanent magnets for polarization.

Located directly above the array of 48 normally used transducers is a similar ring of 48 more transducers. The transducers in this second group are connected in series and are used only for transmission during echo ranging on deep targets. The short vertical length of these transducers produces a broad vertical pattern which insures that sound energy will reach a target at a large depth angle. These transducers are not used for receiving.

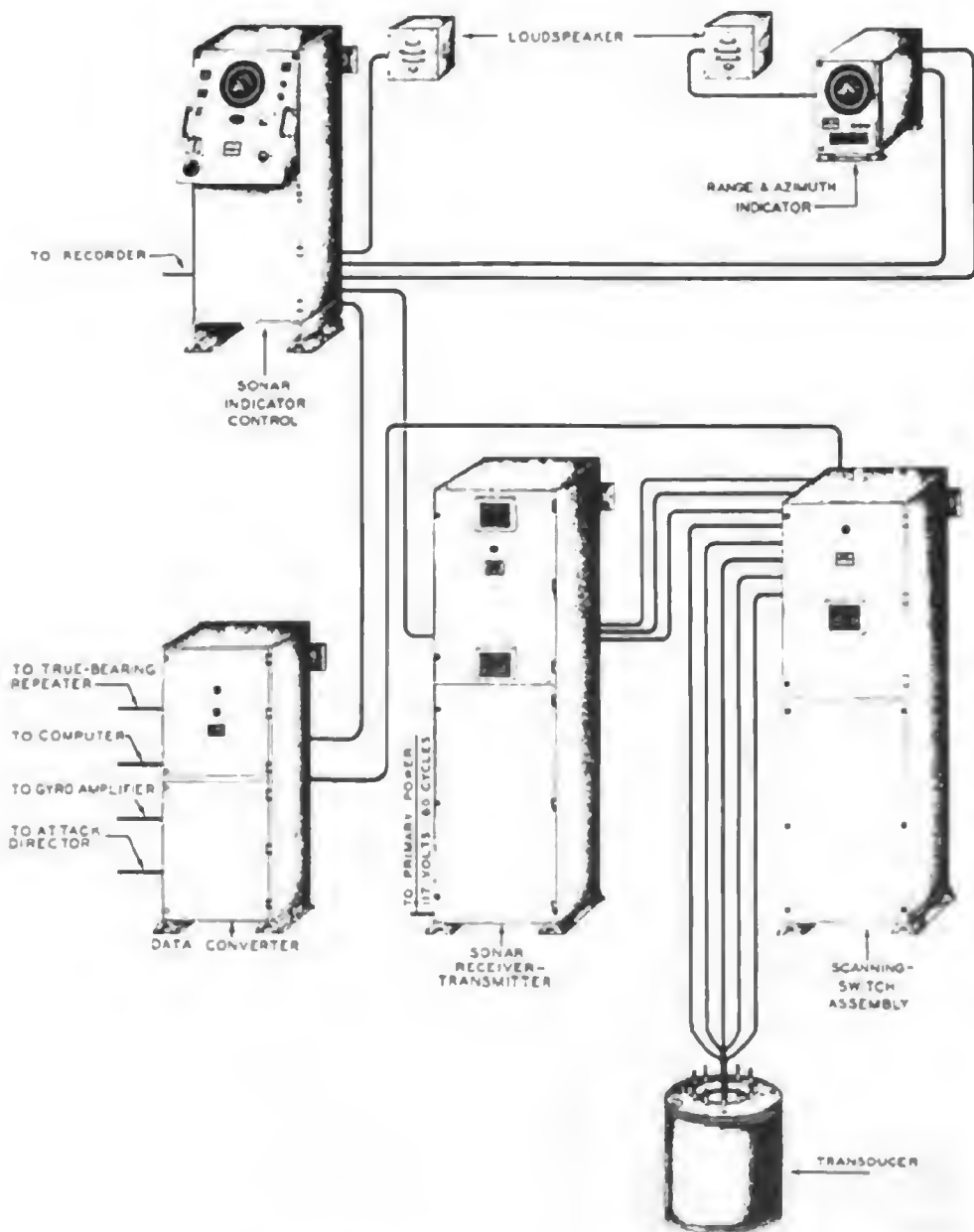


Figure 15-1.—QHB-a scanning equipment.

### Scanning Switch Assembly

A photograph of the scanning switch assembly is shown in figure 15-2: The audio scanning switch is similar to the video scanning switch. At the left end of each of the scanning switches is a circular terminal board to which

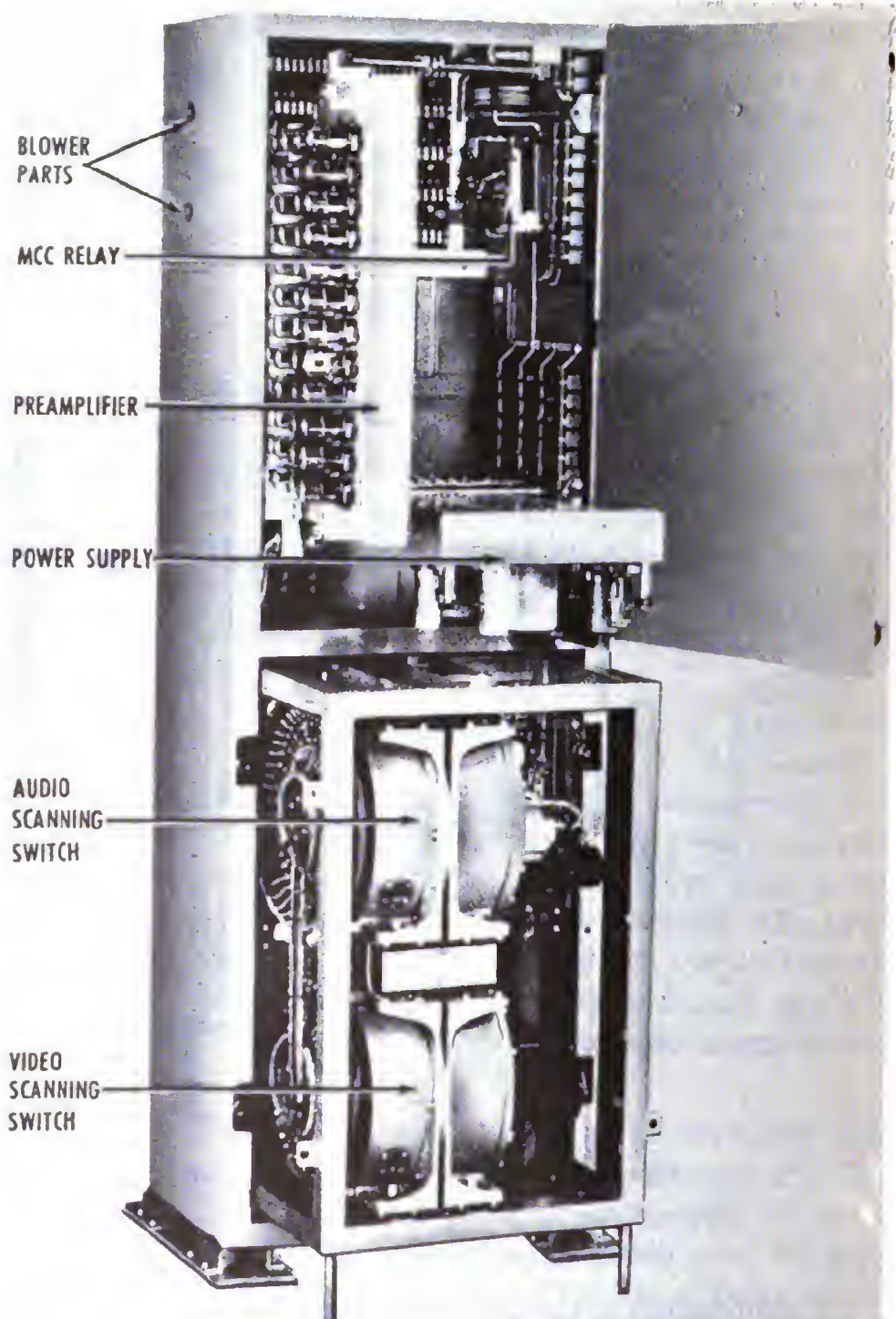


Figure 15-2.—Scanning switch assembly.

the output leads of the preamplifiers are connected. The terminals are connected to pins which protrude through the left side of the scanning switch proper. The pins are insulated from the housing by rubber grommets.

A disk made of mica and glass (the stator plate) is bolted on the inside of the left-hand end bell. The pins go through the end bell and the disk. The surface of the disk is coated with aluminum and scribed with 48 radial divisions forming 48 separate sectors. Each sector is connected to one of the pins. This provides a complete circuit from any specific preamplifier to a corresponding sector.

The rotor of a scanning switch is composed of a disk like the stator plate. It is mounted on a cast-iron backing disk. The rotor is coated with aluminum and scribed. When the sectors of the stator and those of the rotor are lined up, 48 equal capacitors are formed. The capacity of each sector pair ranges from 80 to 100 micromicrofarads.

The capacitors thus formed constitute a means for connecting the preamplifier outputs to an electrical network carried on the rotor assembly. The network provides proper phasing and attenuation so that any 18 consecutive stator signals will form an acoustical beam. The network is mounted in an aluminum can and its leads are connected to slip rings on the rotor shaft.

The rotor of the audio scanning switch is rotated by a servo system. The servo motor is capable of driving the shaft at 8 rpm. The rotor of the video scanning switch is driven by a 3500 rpm motor through a 2-to-1 gear reduction. The rotor is driven continuously by this motor.

A control transformer is driven at a 1-to-1 ratio by the video scanning switch shaft. The excitation winding (rotor) is excited by a d-c current proportional to the sound range. The output of the stator windings is a 3-phase a-c voltage at slightly less than 30 cycles per second. The amplitude of the a-c voltage is proportional

to the sound range. The phase relation between the instantaneous a-c voltage and the instantaneous angular position of the scanning switch rotor is constant.

The a-c voltage is supplied to the deflection coils of the cathode-ray tube. This voltage causes the electron beam to be deflected outward from the center of the screen in a spiral pattern. Therefore, the instantaneous position of the electron beam corresponds to the bearing of the scanning switch and also to the sound range. The echo voltage is applied to the cathode-ray tube as brightening voltage, causing the echo to appear on the screen.

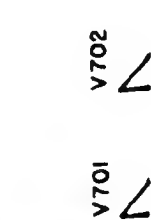
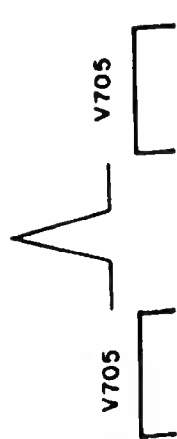
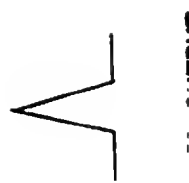
### Receiver-Converter

The outputs of the two scanning switches are fed to the receiver-converter. The receiver-converter has separate audio and video channels. A block diagram of the receiver is shown in figure 15-3. A tunable oscillator in a unicontrol system supplies a signal to the first mixers in both channels and also to a converter which produces the transmitter frequency. In this converter a master 65-kc signal is heterodyned with the signal from the unicontrol oscillator. The difference frequency is the transmitter frequency. The i-f stages of both channels operate on 65 kc.

Reverberation controlled gain (RCG) bias is applied to the two r-f stages of both the audio channel and of the video channel. The MASTER GAIN CONTROL on the front panel of the console is a manual gain control for the r-f stages.

In the audio channel a BFO is controlled, except in the LISTEN condition, by doppler-nullifier circuits. The OWN DOPPLER NULLIFIER (ODN) circuit keeps the audio output of the reverberations at 800 cycles per second. The TARGET DOPPLER NULLIFIER (TDN) circuit keeps the audio output of the target echoes at 800 cycles. The doppler-nullifier







circuits are necessary because of the sharp response of the audio circuits.

A schematic diagram of the receiver is shown in figure 15-4. The circuits of the video channel are conventional in design. The unicontrol oscillator, the tuned r-f stage of the video channel, and the tuned r-f stage of the audio channel are all tuned with a three-section ganged capacitor. Therefore, as the frequency of the transmitter is changed by tuning the unicontrol oscillator, the frequency of the receiver is changed also.

The output of the unicontrol oscillator is fed to the screen grid of the mixer tube in each channel. The bias on the r-f stages in each channel is partly cathode bias and partly fixed bias. The fixed bias is obtained from the voltage drop across the master gain control R106. RCG bias is applied to the control grid of the r-f stages in both channels. The output of the video channel is fed to the cathode-ray tube.

The r-f stages and the first mixer of the audio channel are conventional in design. The screen grid of the second mixer is connected to the output of the BFO. The frequency of the BFO output is 65.8 kc and the frequency of the echoes is 65 kc. The two signals heterodyne to produce a difference frequency of 800 cycles. The output of the second mixer is coupled to both control grids of V710.

The output of one half of V710 is coupled to the audio output amplifier V711. When the doppler-nullifier relay K703 is closed, a peak filter is connected from the plate of V710 (pin 2) to ground. The peak filter, L709 and C713, attenuates frequencies other than 800 cycles per second.

The other half of V710 provides a signal to the discriminator circuit. The discriminator can vary the frequency of the BFO so that the audio output always remains at 800 cycles. Because of the narrow band pass of

the audio stages, any Doppler will change the frequency of the echo and of the reverberations to such an extent that the resultant audio signal will not pass through the audio stages. To correct the frequency of the BFO and keep the audio signals at 800 cycles the discriminator controls two reactance tubes. They change the frequency of the BFO and remove the effect of the Doppler.

The ODN sampling relay K702 is shown in its open position on the schematic. However, its normal position is closed. When no keying pulse is present, the grid of V713 (pin 4) is biased positive and the tube is conducting heavily. The plate current flows through the sampling relay and it remains closed. When a keying pulse is present, it drives the grid further positive and has no effect on the relay.

Immediately after the end of the keying pulse the grid is driven negative because of the discharge of capacitor C723. The sampling relay now opens, connecting the output of the discriminator to capacitor C710 through resistor R858 and the relay contacts. Capacitor C710 charges. When capacitor C723 in the grid circuit of V713 discharges sufficiently, the tube again conducts. This closes the sampling relay, which disconnects the output of the discriminator from C710. The relay remains closed until the end of the next keying pulse. The charge placed on C710 controls the ODN reactance tube for the remainder of the time until the next keying pulse.

The discriminator output is fed to the TDN circuit when the sampling relay opens. The discriminator output coupled through contacts 2 and 3 of the ODN sampling relay and contacts 5 and 6 of the doppler nullifier relay appears across C709 and R785. This voltage sets the reference bias on the TDN reactance tube. During the sampling period (when the sampling relay is open), contacts 4 and 5 short capacitor C709 to ground and remove any previous charge.





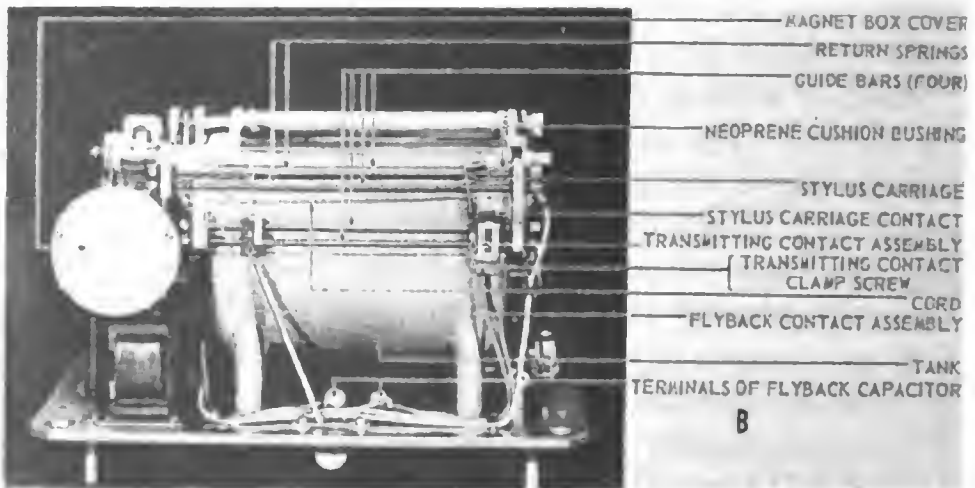
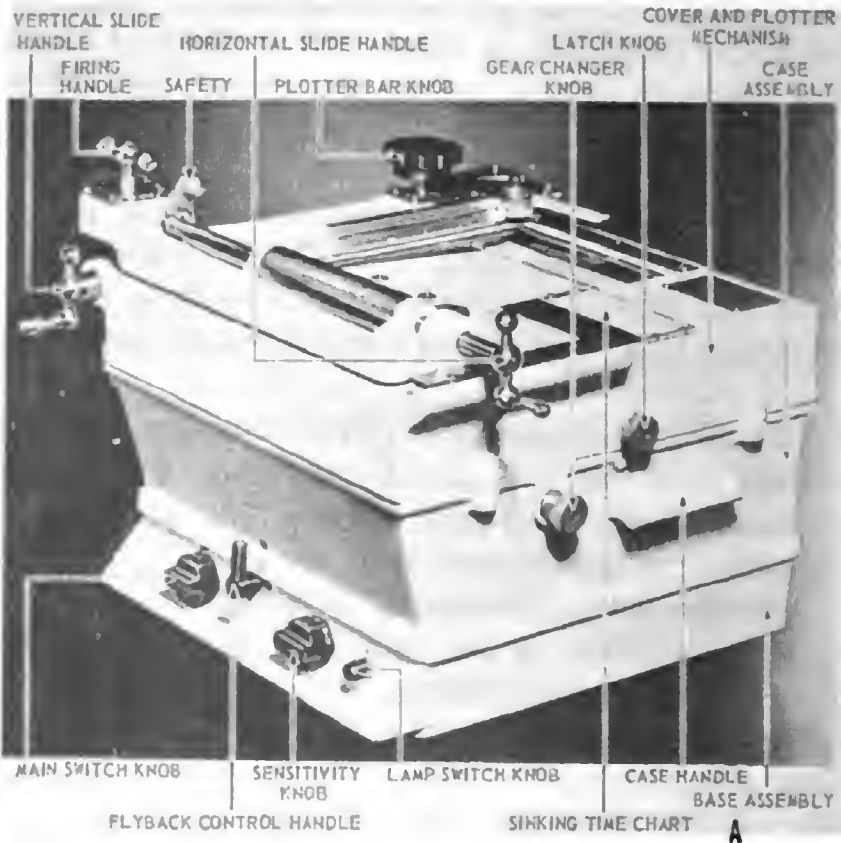
The d-c voltage from the discriminator is positive when the audio frequency is above 800 cycles and negative when the frequency is below 800 cycles. The TDN circuit operates after the first 250 yards of sound range, and any variation in the Doppler controls the reactance tube. The ODN is sampled after the transmitted pulse. The d-c reference voltage from C710 is affected only by leakage of this capacitor. The reference voltage on the ODN reactance tube is constant until the next sampling period.

The RCG and time-varied gain (TVG) voltages are the same voltage but the two terms are used to indicate different rates of decay of the voltage. The purpose of the TVG refers to the normal gain recovery in the absence of reverberation whereas RCG refers to the fact that the gain recovery is delayed in proportion to the amplitude of the reverberations. The purpose of the RCG bias is to lower the gain of the receiver immediately after the transmitted pulse. During this time the amplitude of the reverberations is very high. As the reverberations decrease, the gain of the receiver is gradually restored to normal.

Half of V713 is normally cut off by a negative voltage on its grid. The cathode is held at about -60 volts, obtained from a voltage divider across the -105 volt supply to ground. When the keying pulse is applied to the grid, the tube conducts and charges C715. This charge is negative with respect to ground and comprises the RCG bias.

If no reverberations are present, the charge on C715 is quickly removed by conduction in the right half of V712, thus rapidly increasing the receiver gain. The left half of V712 rectifies the reverberations coupled through C767 from the audio output tube. The rectified portion of the reverberations appears across R755 and C714. This voltage acts as bias on the right half of V712.

The bias from the reverberations prevents the right



**Figure 15-5.—CAN-55070 range recorder. A, External view, B, internal mechanism.**



half of V712 from conducting and from discharging C715; therefore, the only path for this capacitor to discharge is through the high resistance of R758. Thus, receiver gain recovers slowly during the time C715 is discharging through R758. After the reverberations have decreased sufficiently, the diode (pins 5 and 8) conducts and quickly removes the charge on C715. The gain of the receiver is now restored to normal. This circuit is similar to the RCG circuit in the QGB sonar.

## RANGE RECORDER

The CAN-55070 range recorder is a device for recording graphically the echoes received by sonar equipment. The action of this particular recorder is similar to that of the range recorder in the QGB sonar equipment. A photograph of the CAN-55070 range recorder is shown in figure 15-5, A.

The roll-feed mechanism, stylus assembly, magnetic clutch, and gear-change box are almost identical with those used in the QGB. When in operation, the recorder controls the keying of the transmitter. The tactical use of the recorder is not described here; only the mechanical and electrical features are discussed.

A photograph of the internal mechanism of the recorder is shown in figure 15-5, B. A set of movable contacts controls the travel of the stylus. As the range to the target decreases, there is no need for the stylus to travel all the way across the paper. By moving the flyback contacts, the distance the stylus travels may be shortened.

A wiring diagram of the recorder is shown in figure 15-6. The contacts of relay 800439 are normally closed and the d-c voltage from the power supply is applied across the magnetic clutch and series resistor 800201. In this condition the clutch is energized and the stylus is drawn across the paper. When the stylus carriage con-

tact on the bottom of the carriage reaches and closes the circuit at the flyback contact, d-c voltage from the power supply is applied to relay coil 800439, resistor 800111, and resistor 800110. These components are connected in series. Flyback capacitor 800682 is connected in parallel with the relay coil and resistor 800111.

Current through relay coil 800439 causes its contacts to open, breaking the circuit to the magnetic clutch, and causing the stylus to return to its starting position. After the flyback contacts open (that is, when the stylus begins to move toward the starting position), the circuit to relay coil 800439 is opened. However, capacitor 800682 discharges through the relay coil and keeps the relay contacts open. The relay will not close until the capacitor discharges a certain amount; the length of time that the relay remains open is sufficient to allow the stylus to return to its starting point and remain there a short time.

The keying rate of the transmitter depends on two things—the setting of the flyback contact and the discharge of capacitor 800682. As the flyback contact is moved to the left, the stylus travel is shortened and, therefore, the transmitter is keyed at a greater rate. When the capacitor discharges sufficiently, relay 800439 closes, the magnetic clutch is energized, and the cycle repeats. The resistor-capacitor unit 800202 is connected in parallel with the relay contacts to reduce sparking at the contacts.

Shortly after the stylus begins to move to the right, the stylus carriage contact closes the transmitting contacts and the transmitter sends out a pulse. The leads from the sonar receiver are brought to the primary of transformer 801077. The sensitivity control is used to adjust the amplitude of the signal to the signal rectifier. This rectifier is the metallic-oxide type with its output connected to the stylus.

The paper used in the range recorder is sensitive to





the passage of electric current, being similar to that used in the NMC-2 fathometer described previously. A mark is made on the paper when a pulse is transmitted and also when an echo is received.

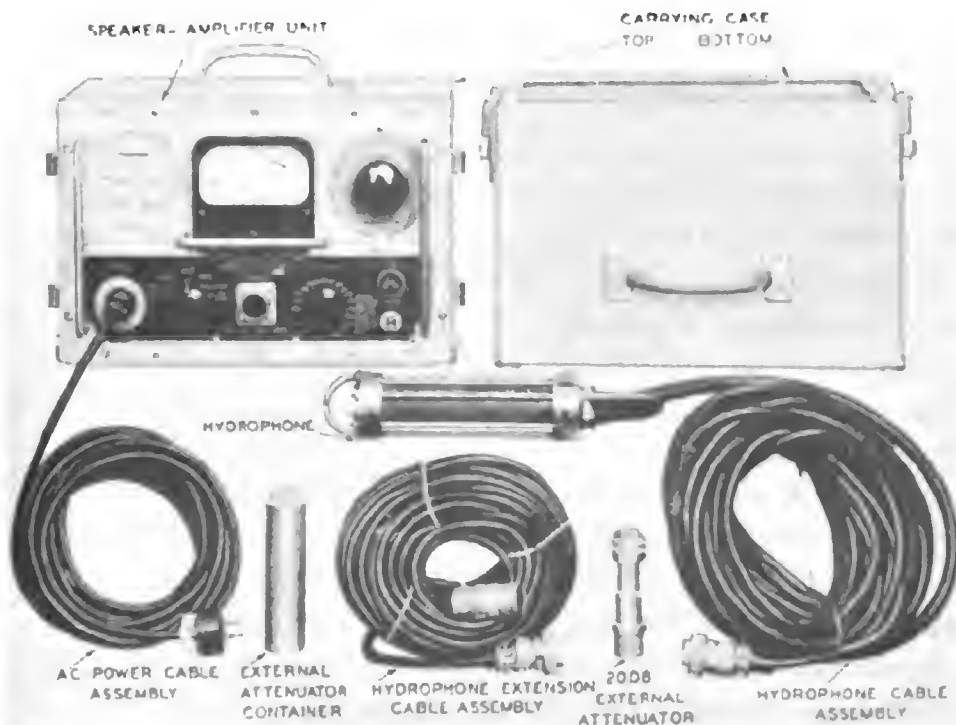


Figure 15-7.—OAX underwater sound testing equipment.

One of the most important adjustments to the range recorder is the zero-zero adjustment. The accuracy of the firing information depends on this adjustment. Information for making the zero-zero adjustment is contained in the instruction book.

### **OAX UNDERWATER-SOUND TESTING EQUIPMENT**

The OAX is a portable equipment which can be used for the following operations: Tuning a sonar transmitter and receiver; plotting the transmitter frequency-response curve; plotting the receiver frequency-response curve; plotting the directivity pattern of the transducer; checking the BDI; and checking the overall efficiency of the sonar system. A photograph of the OAX is shown in figure 15-7.

The OAX consists of two units—an amplifier and a hydrophone of the magnetostriction type. The cable which connects the hydrophone to the amplifier is long enough for the amplifier to be placed beside the sonar equipment while tests are being made.

The hydrophone is dropped over the side of the ship and lowered to the same depth as the sonar transducer. The transducer is trained directly at the hydrophone. The sonar transmitter is tuned by adjusting it for maximum meter reading on the OAX. In this operation the OAX is used as a receiver. Placing the selector switch on the OAX in the SEND position changes the OAX into a low-power transmitter. The sonar receiver is then tuned for maximum output.

The OAX contains an accurate oscillator which controls the frequency, when the OAX is used in the SEND position. This oscillator is used as a BFO, when the selector switch is in the BEAT position. To measure the sonar transmitter frequency, the hand key on the sonar transmitter is depressed and the oscillator dial of the OAX is tuned for a zero beat. The frequency is read from the oscillator dial, which is calibrated from 17 to 26 kc.

## ATTACK PLOTTER MARK 1

The attack plotter (figure 15-8) is an electronic equipment designed as an aid in conducting antisubmarine attacks. The attack plotter receives OSC, speed from the Dead Reckoning Analyzer (DRA), and target information from the sonar equipment. This information is used by the attack plotter to develop automatically on the screen of a cathode-ray tube a plot of the following information: (1) Own-ship course (OSC); (2) the path of each sound beam; (3) the position of the underwater target, when each sound contact is made, and the course of the

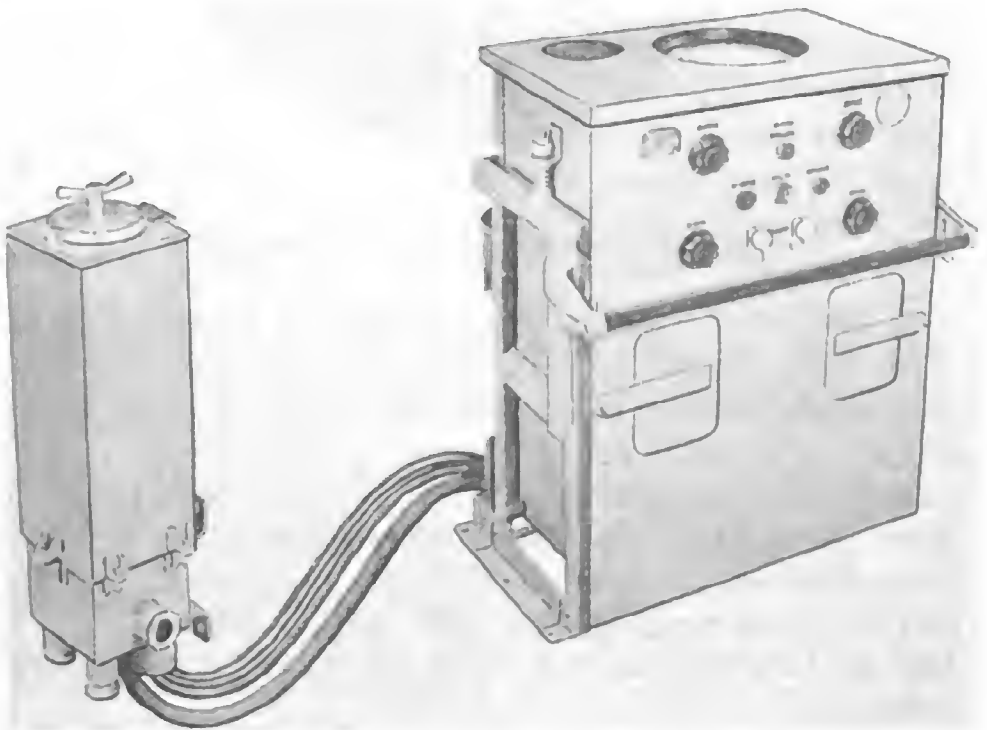


Figure 15-8.—Attack Plotter Mark 1.

target as successive target positions appear; and (4) the firing range and proper bearing for the forward thrower weapons in order to determine correct train and firing time.

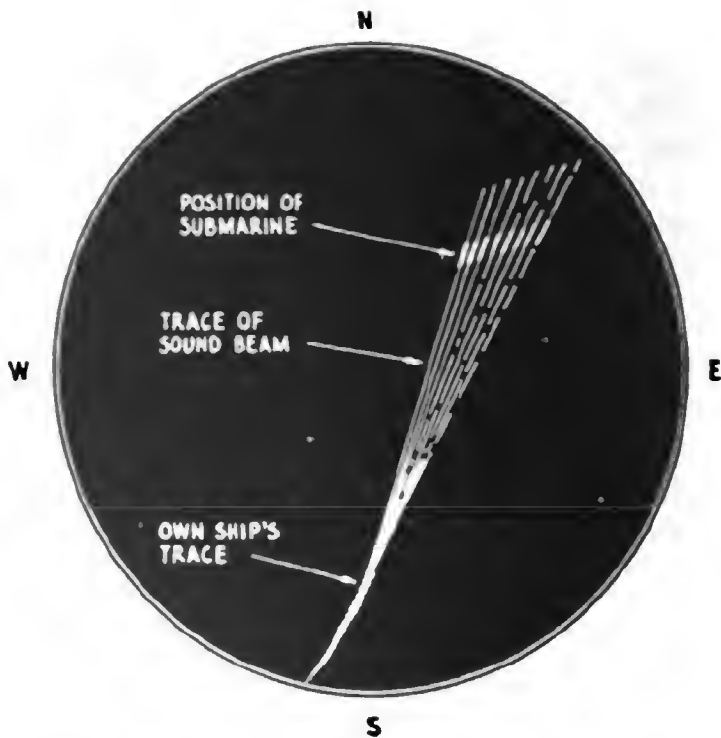


Figure 15-9.—Sample plot on the attack plotter.

A sample plot on the attack plotter is shown in figure 15-9. OSC is depicted by a succession of bright spots. A spot is produced on the screen each time the sonar transmitter is keyed. The persistence of the screen is long enough that the spot remains visible for about two minutes. The path of each underwater sound beam is traced by a small spot which moves across the screen from the last own-ship position. The spot returns automatically to the new own-ship position each time the sonar transmitter is keyed.

The small spot leaves a persistent mark on the screen each time an echo is received. A series of these marks shows the target course and speed. The own-ship position is derived from information produced in the DRA.

The DRA receives OSC from the gyrocompass and speed from the pitometer log. It combines the two quantities and provides an output of N-S and E-W components.



This information is transmitted to the attack plotter by a step-by-step transmission system, which is similar in operation to synchro transmission except that d-c voltages are used.

The transmitter in a step-by-step system is a commutator which makes and breaks connections to the step-by-step receiver. The receiver is a system of electromagnets and a soft-iron armature. The electromagnets are arranged so that they turn the armature. The step motors in the attack plotter control the action of the electron beam in the cathode-ray tube.

### **QDA TARGET-DEPTH DETERMINING EQUIPMENT**

The QDA target-depth determining equipment measures the sound range and the depression angle of a submerged submarine. This equipment is basically the same as other echo-ranging gear. The transducer is designed to have a broad pattern in the horizontal plane, but cannot be trained in azimuth. The pattern is broad enough to cover the area  $60^\circ$  on either side of the bow of the ship. The transducer has a narrow beam in the vertical plane and is pivoted about a point on the athwartship axis to permit the beam to be tilted.

When the beam is directed at a target, the tilt of the transducer at the time maximum echo signal is received is the approximate depression angle of the target. To center the beam on the target accurately, the depression-deviation indicator (DDI) is used. The DDI operates like the bearing-deviation indicator (BDI) except that, instead of indicating errors in azimuth, it indicates errors in depression.

If the sound range and the depression angle are known, the horizontal range and the depth can be computed by the principles of trigonometry. This computation is performed automatically in the model OKA sonar resolving equipment. The depth appears on a recorder similar to the range recorders discussed previously.

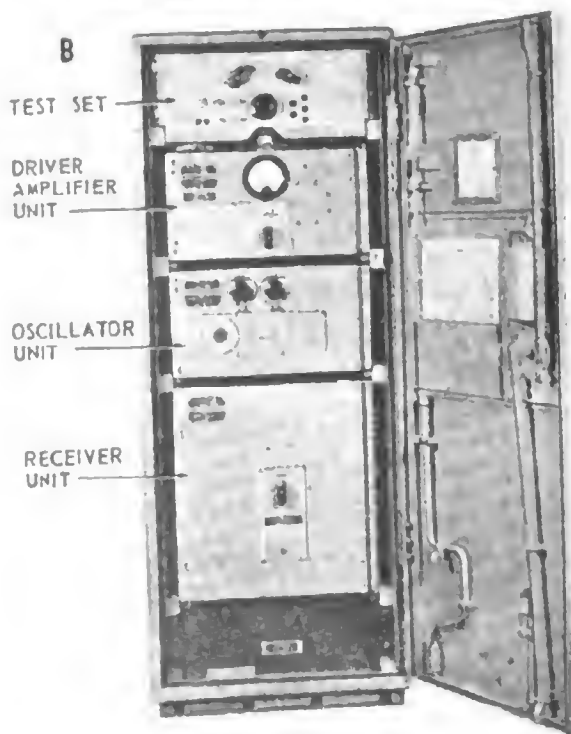
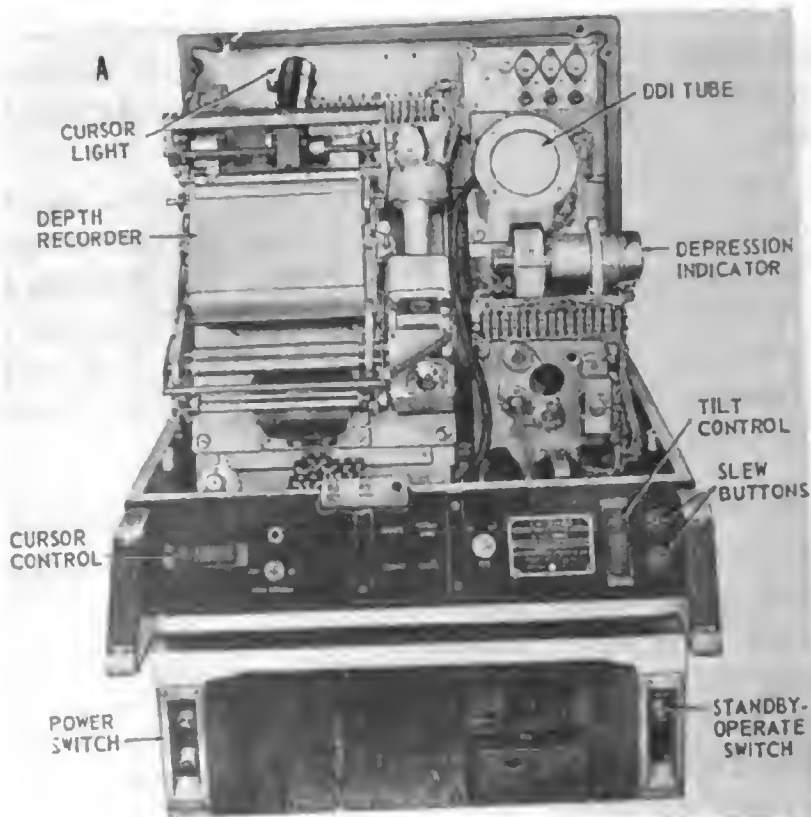


Figure 15-10.—QDA units.  
A, Console with cover removed; B, transmitter assembly.

A photograph of the console of the QDA is shown in figure 15-10, A. The console contains the depth recorder and the DDI. The transceiver (figure 15-10, B) operates on a frequency between 50 and 60 kc. The high operating frequency of the QDA limits the maximum range, but makes possible the use of a highly directional transducer. Other units of the QDA are the tilt amplifier which controls the tilt of the transducer, several power supplies, a voltage regulator assembly, a hoist-tilt mechanism, a transducer, and stabilizing equipment.

Usually the QDA is not installed by itself. It is customarily used in conjunction with the OKA resolving equipment and the QHB scanning sonar.

## PURPOSE OF LISTENING EQUIPMENT

Equipment designed only for shipboard listening purposes is usually installed aboard submarines. Most ech-ranging equipment has provisions for listening. A simple form of listening equipment is nothing more than a hydrophone connected to an amplifier and headphones.

Vessels traveling through the water make considerable sound, and these sounds can be detected with listening equipment. Different types of vessels make different sounds. The propeller noise of a destroyer is much different from that of a slow transport.

If the hydrophone is made directional, the operator can determine the bearing of the sound source by training the hydrophone for maximum output from headphones or a loudspeaker. A vessel underway makes not only sonic sounds but also ultrasonic sounds.

When a hydrophone is used for ultrasonic listening, the directivity is greater than when the same hydrophone is used for sonic listening. The directivity pattern becomes sharper for ultrasonic listening because of the shorter wavelengths of ultrasonic sound. The result is more accurate target bearings. Sonic sounds may be detected at

greater ranges, since ultrasonic sounds suffer greater attenuation. However, unless a system of triangulation is used, no range information can be obtained from listening equipment.

A surface vessel makes considerable noise due to the propeller and machinery on board. The amount of sound thus produced is much greater for a surface vessel than for a submarine. When a surface vessel is using listening equipment, this sound interferes with the detection of sound originating outside the vessel. This is particularly apparent when a surface vessel is trying to detect the relatively small amount of sound made by a submarine. The effect is that the sound made by a surface listening vessel tends to mask the sound made by other vessels.

Listening is done chiefly from submarines, and the small amount of sound made by a submarine makes it possible to detect surface vessels rather easily. Since a submarine commander usually does not want to make the presence of his submarine known, he hesitates to use echo-ranging equipment because it can be detected by other listening equipment.

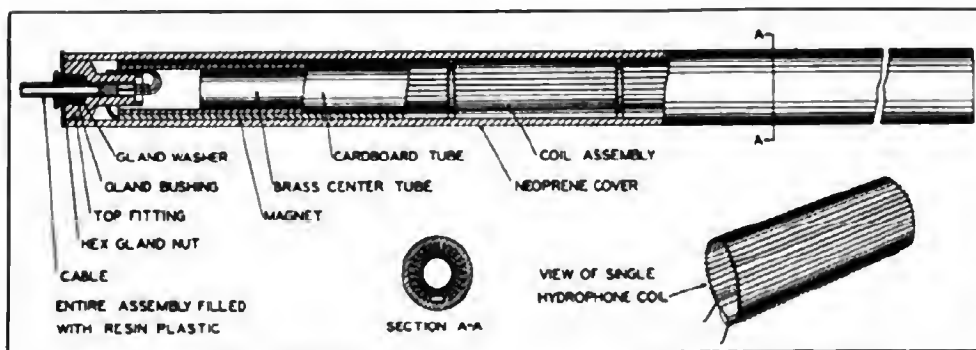
## HYDROPHONES

The hydrophone used in listening equipment may be either of the magnetostriction or crystal type. Most echo-ranging equipment has provisions whereby the operator can disable the transmitter and use the equipment for listening. The transducer of the echo-ranging equipment is then considered as a hydrophone.

Several different projectors for echo-ranging equipment have been illustrated in previous chapters. However, the frequency range covered by these transducers is limited. In the QGB sonar described in chapter 14 the tuning range is between 17 and 26 kc. Another point to remember is that these transducers are relatively frequency sensitive and not satisfactory for sonic listening.



**Figure 15-11.—Hydrophone installed with JT listening equipment.**



**Figure 15-12.—Cross-sectional view of the hydrophone used with JT.**

The hydrophone in JT listening equipment can be used for sonic as well as ultrasonic listening. A photograph of this hydrophone is shown in figure 15-11. This is a magnetostriction type hydrophone and consists of ten toroidally wound coils connected in series and mounted in line on a brass support tube. A heavy outer jacket of neoprene covers the coils and the entire hydrophone assembly except the support tube.

Each coil is wound on a nickel tube and magnet assembly. The magnet is used for polarization. The design of the windings is such that the hydrophone is directional. A cross-sectional view of the hydrophone is shown in figure 15-12. It is approximately 65 inches in width. This is considerably greater than the width of transducers used in echo-ranging equipment.

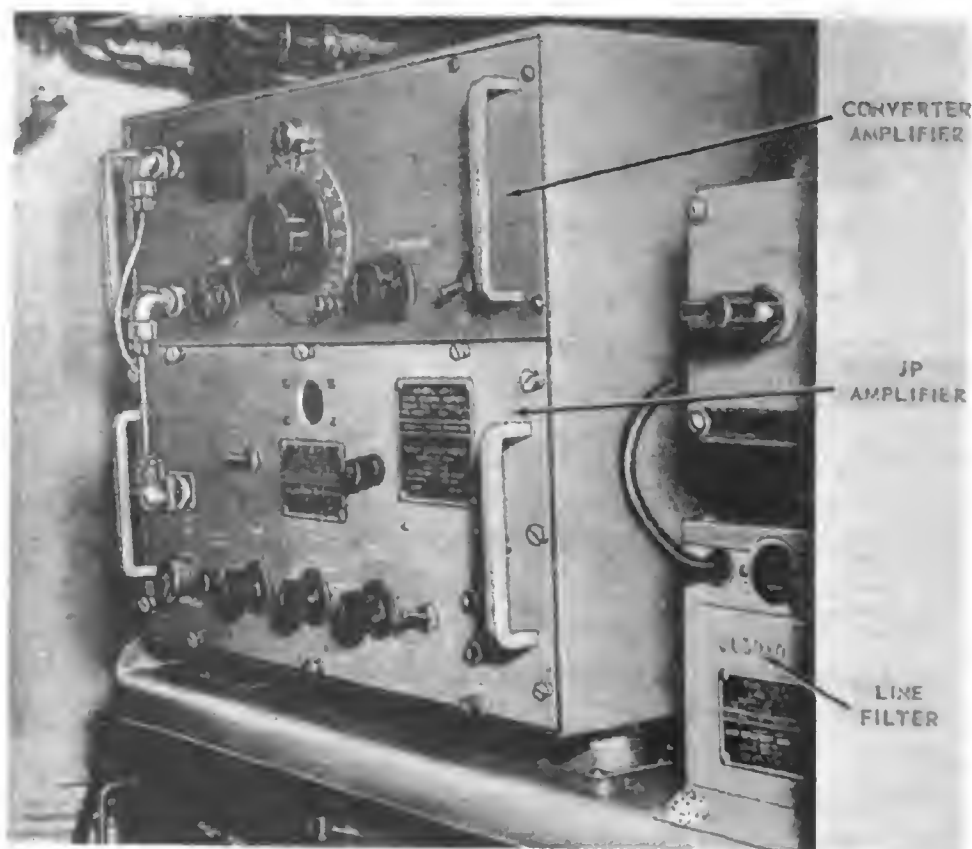
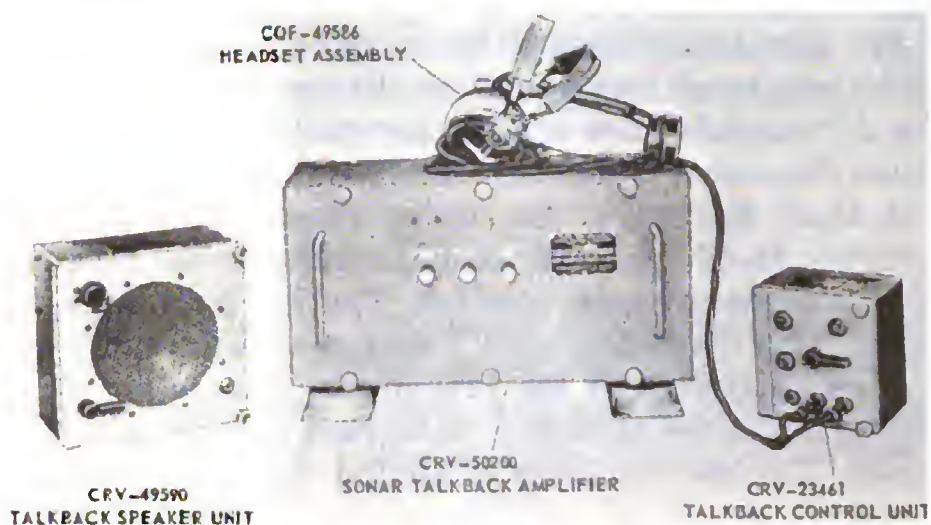
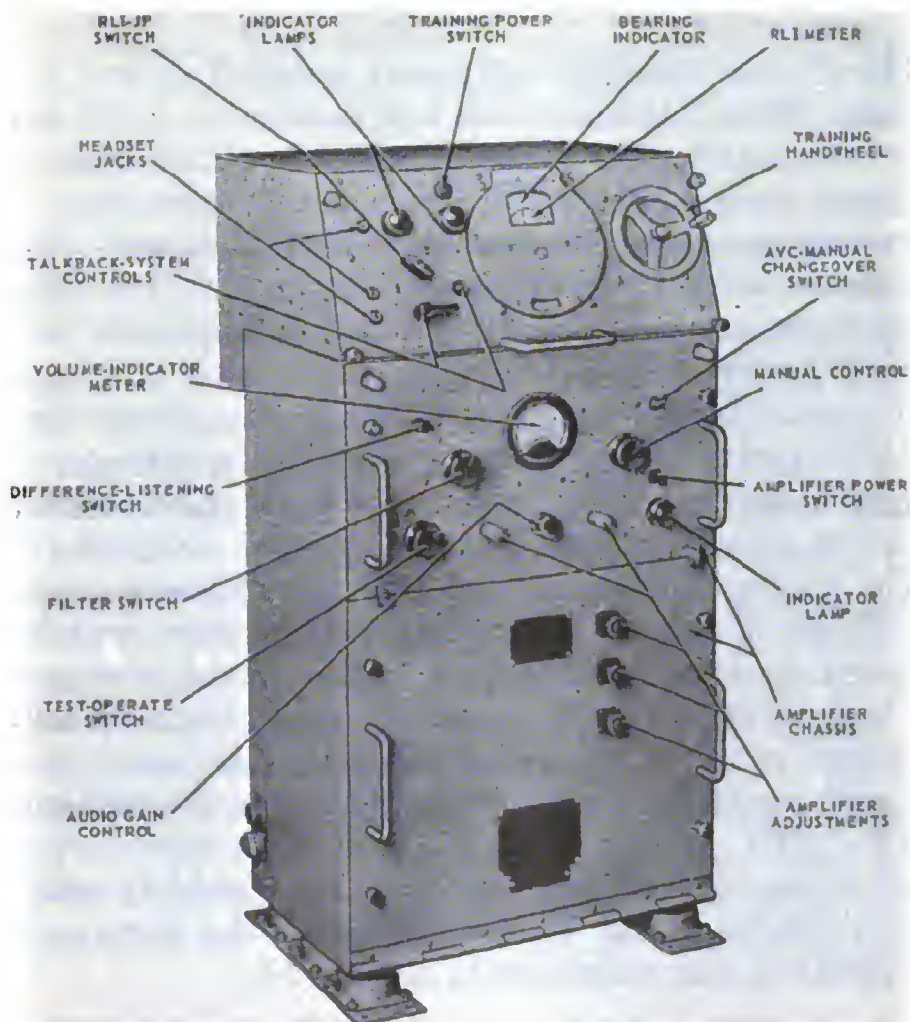


Figure 15-13.—JP listening equipment.



**Figure 15-14.—Master control unit and sonar talkback system.**

## JT LISTENING EQUIPMENT

The JT is a listening equipment installed aboard submarines. With this equipment it is possible to detect surface vessels and other submarines and to obtain bearings on these vessels. The JT includes the JP amplifier, an ultrasonic converter, a master control unit, and other associated units. Its hydrophone (figure 15-11) is directional in the horizontal plane and may be trained by hand or by a power drive.

A photograph of the JP amplifier (lower illustration) and ultrasonic converter (upper) is shown in figure 15-13. The hydrophone is mounted topside. Since this is strictly listening equipment, only bearings can be obtained.

The master control unit and the sonar talkback system are shown in figure 15-14. The master control unit is a listening equipment in itself. A relay is used to connect the output of the hydrophone to either the ultrasonic converter or to the master control unit. The master control unit operates on a principle similar to the BDI and, like the BDI, gives a right-left indication. However, instead of having a cathode-ray tube, the right-left indication is obtained from a meter. When all the above units are installed, the equipment is called a JT.

### Ultrasonic Converter and JP Amplifier

For ultrasonic listening the converter and the JP amplifier are used together. The ultrasonic converter and the JP amplifier are straightforward in design. A detailed discussion is not included in this chapter.

A block diagram of the ultrasonic converter is shown in figure 15-15. The converter is similar to the front end of a superheterodyne receiver. The input is ultrasonic sound from the hydrophone. This signal is heterodyned to a lower frequency in the first mixer. The output of the first mixer is fed through a band-pass filter to the second mixer. The second mixer is similar to a BFO arrange-



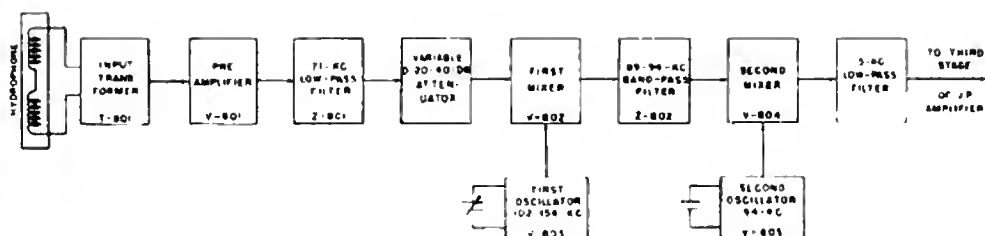


Figure 15-15.—Block diagram of the ultrasonic converter.

ment. The output from the second mixer is an audio signal. The only tuning control is the capacitor which varies the frequency of the first oscillator. The output of the converter is fed to the JP amplifier.

A block diagram of the JP amplifier is shown in figure 15-16. This is an audio amplifier. For sonic listening the converter is bypassed and the hydrophone is connected directly to the input of the JP amplifier. The audio output is fed to the sonar talkback unit and then to the operator's headphones. An unusual feature of the JP is that it is operated from a 115-volt d-c source. If the a-c system should fail, this equipment will continue to operate from the submarine's batteries. However, when this happens the hydrophone has to be turned by hand, since the training system operates from alternating current only.

Two indications enable the operator to determine when the hydrophone is trained exactly on the target. One indication is maximum output from the headphones. The other indication is maximum closure of the tuning eye. The tuning eye provides an indication only when the JP amplifier is in operation.

### Master Control Unit

A block diagram of the master control unit is shown in figure 15-17. The master control unit is strictly a sonic unit. The hydrophone is split into two sections like the transducer used for BDI operation. Two transformers

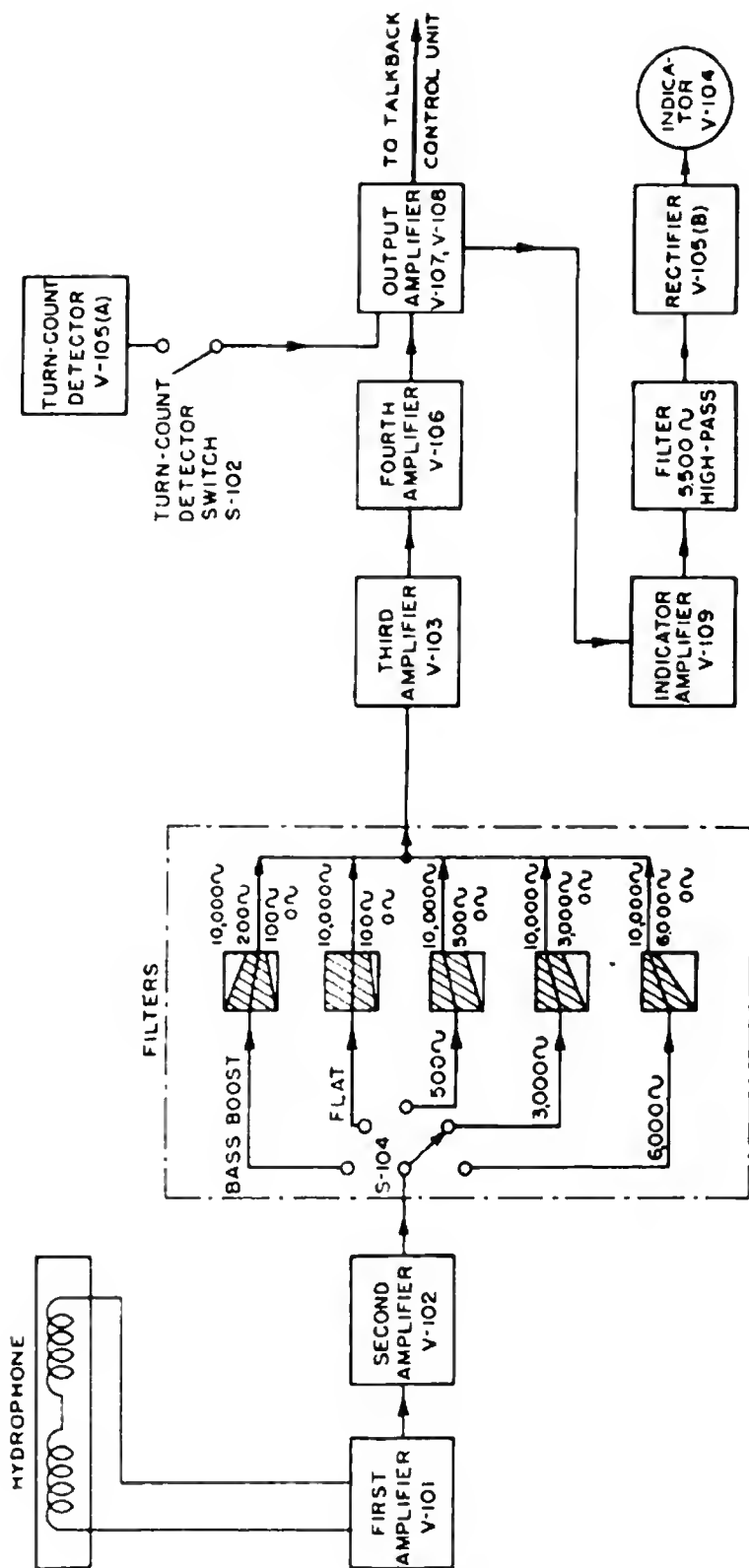
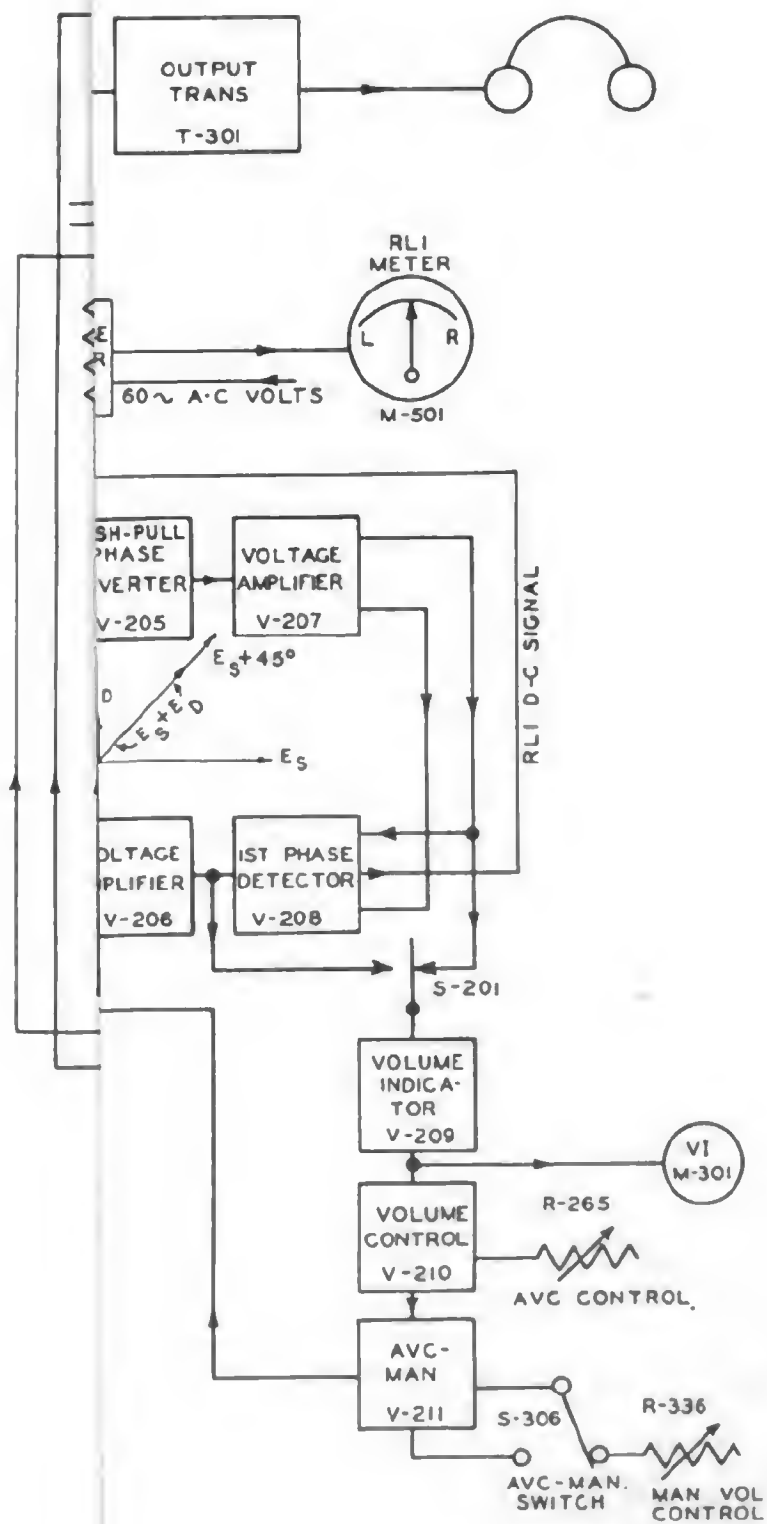


Figure 15-16.—Block diagram of the JP amplifier.





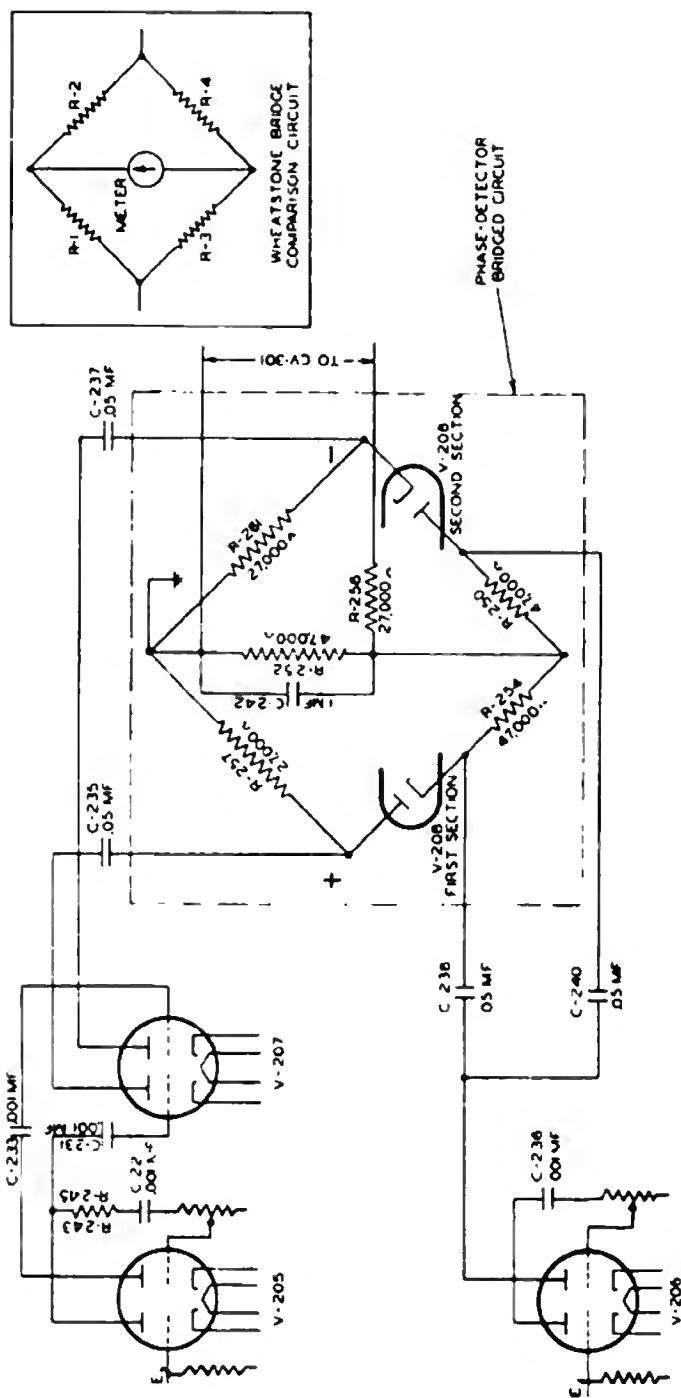


Figure 15-18.—Simplified schematic diagram of the first phase detector circuit.

are used to obtain the sum and the difference of the signals from the two halves of the hydrophone.

The sum and difference signals pass through separate amplifiers and are shifted in phase by phase shifters. The phase of the sum signals is advanced  $45^\circ$  and the phase of the difference signals is advanced  $135^\circ$ . Regardless of the angle of the hydrophone with respect to the sound source, the sum signals and the difference signals are  $90^\circ$  out of phase in the preamplifier circuits, provided the hydrophone is not on target.

The result of the phase shifting is that the sum and difference signals are either in phase or  $180^\circ$  out of phase at the output of the phase shifters. If the hydrophone is trained to the right of the target, the sum and difference signals are in phase. If the hydrophone is trained to the left of the target, the sum and difference signals are  $180^\circ$  out of phase. If the hydrophone is trained directly on the target, the difference signal is zero.

A simplified schematic diagram of the first phase-detector circuit is shown in figure 15-18. This circuit is similar to a Wheatstone bridge. The sum signal after it has been shifted in phase is applied to the grid of the first section of V205. The two twin triodes, V205 and V207, are connected so that the output of V207 is a push-pull sum signal. This push-pull signal is applied to the plate of the first section of V208 and to the cathode of the second section of V208. When the plate of the first section is positive, the cathode of the second section is negative. Then both diodes conduct equally and no current flows through resistor R252. In this condition the bridge is balanced.

When the bridge is balanced, the hydrophone is trained exactly on target. On the negative half cycle of the sum signal, the plate of the first section of V208 is negative and the cathode of the second section is positive. Then no current flows through either section of V208.

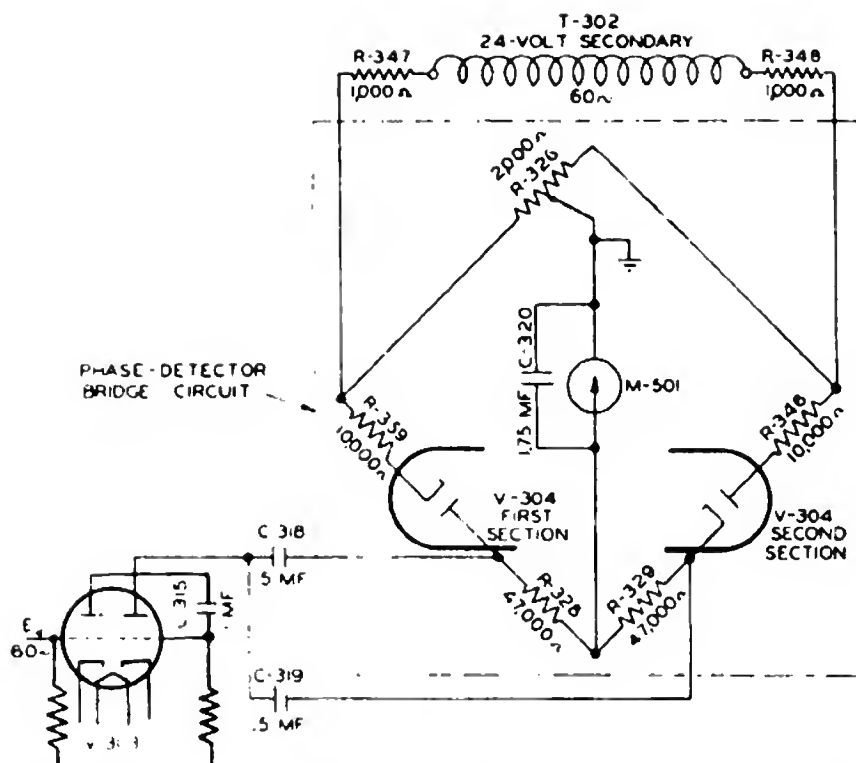


Figure 15-19.—Simplified schematic diagram of the second phase detector circuit.

When the hydrophone is not on target, a difference signal appears at the output of V206. The difference signal unbalances the bridge. The direction in which current flows through resistor R252 depends on whether the hydrophone is trained to the left or to the right of the target.

The voltage developed across resistor R252 is connected to the grid of V303 (figure 15-17) through an interrupter CV-301. The interrupter breaks the input to the grid 60 times per second. Therefore, the output of V303 is either negative pulses or positive pulses with a frequency of 60 cycles. The output of V303 is coupled to a dual triode V304 in the second phase detector circuit shown in figure 15-19. The output of V303 is fed to a bridge circuit. This circuit is similar to the first phase-detector circuit.

The cathode of the first section of V304 and the plate of the second section of V304 are connected to a 24-volt a-c transformer. When the cathode of the first section is negative and the plate of the second section is positive, the two diodes conduct, the bridge is balanced, and no current flows through the meter. Whenever there is an output from the first phase detector circuit, pulses appear at the output of V303 and the bridge is unbalanced. The direction of the current through the meter depends on the polarity of the pulses applied to the bridge.

The RLI meter is of the center-zero type, with the center of the scale being the on-target position. When the hydrophone is trained to the right of the target, the meter deflects to the left, indicating that the hydrophone should be trained left to bring it on the target. If the hydrophone is trained to the left of the target, the meter deflects to the right, indicating that the hydrophone must be trained right to bring it on the target.

An audio output from the master control unit may be connected to headphones. Either the output of the sum channel or the output of the difference channel may be selected. Also, a portion of either the sum or difference channel signal is used to actuate the volume-indicator meter. The function of the volume indicator is similar to that of the tuning eye used in the JP except that more accurate indications are possible with the meter.

The sonar talkback system is an intercommunication system used for communication between the operator and the conning tower. Audio signals from the listening equipment can be connected to this system so that personnel in the conning tower can hear them.

## SOFAR

The word "sofar" is a combination of the first letters of the words "SOund Fixing And Ranging." Sofar is a means of receiving an underwater sound signal and locat-



ing its source. A sofar network has been established as part of an air-sea rescue system. It utilizes the long-distance transmission of sound through sea water to fix the position of aircraft forced to make emergency landings at sea.

A natural sound channel exists in many parts of the ocean. An ideal channel extends from a depth near the surface to approximately 12,000 feet. It has an acoustical center generally between 1500 and 4000 feet below the surface. If a small bomb is exploded near this center, the

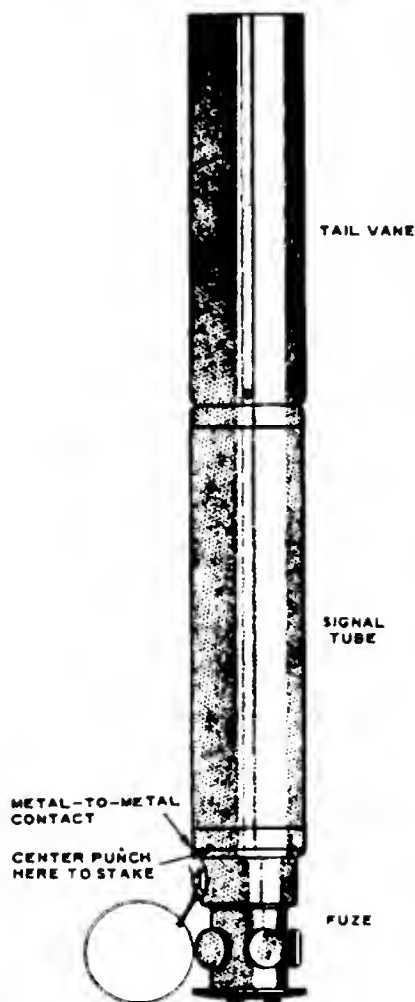


Figure 15-20.—Signal (Underwater Sound) Mk 22 Mod 0.

sound is trapped in the channel and can be received at ranges up to 3000 miles.

One of the bombs used in sofar is shown in figure 15-20. It is designated as a Signal (Underwater Sound) Mk 22 Mod 0. It contains 4 pounds of TNT and has a hydrostatic fuse which may be set to explode the signal at any one of six depths between 1500 and 4000 feet.

The sofar network consists of several widely separated shore-based listening stations. Each station has a listening equipment which is connected to a hydrophone. This hydrophone is located in the ocean near the center of the sound channel.

Since the sound from the bomb radiates in all directions at a nearly uniform rate, it is possible to compute the location of the sound source by comparing the times when the signal is received at the various listening stations. After the signal is received at all the stations, the position of the source may be determined in a matter of minutes.

The output of the listening equipment is recorded on paper tape by means of a power-level recorder. This record shows the arrival time of the sound from the bomb at the station and also the amplitude of the sound. A photograph of an actual tape is shown in figure 15-21. The sound gradually builds up to a peak. The time at which the peak occurs is the time used in the calculations to obtain a fix.

The time is automatically recorded on the tape by a series of marks at the top of the tape. The interval between marks is one second. The time information originates from a chronometer at the station. The chronometer is corrected by using time ticks from a primary standard. The sound signals may be shown on an oscilloscope and with proper equipment may be recorded photographically.

A simple example of the principle used in obtaining sofar fixes is shown in figure 15-22. The three listening

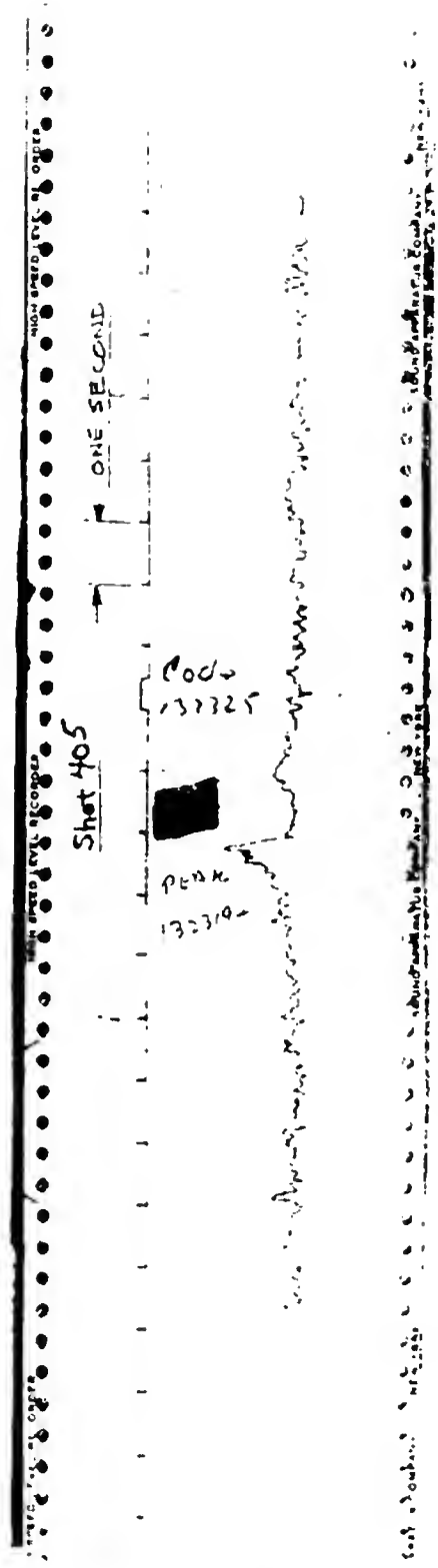


Figure 15-21.—Sofar signal on a level-recorder tape.

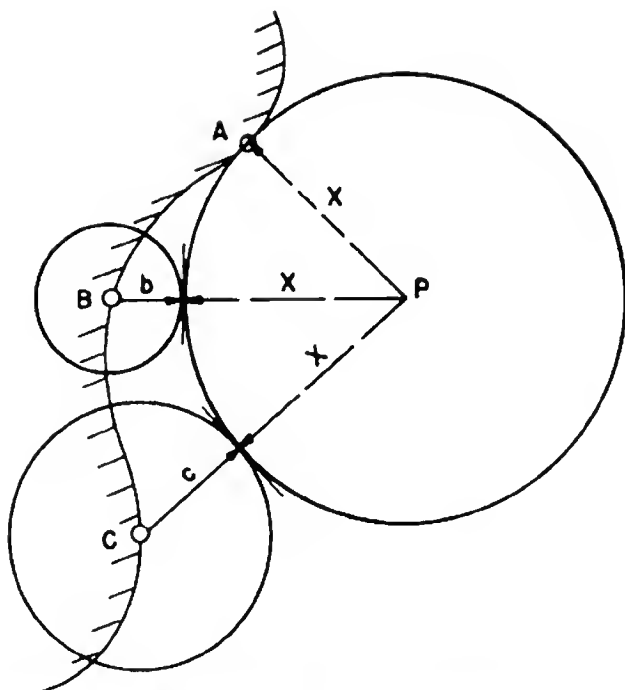


Figure 15-22.—Principle used in obtaining a sofar fix.

stations are located at points A, B, and C. A bomb is exploded and the stations receive the sound at the times indicated. Notice that the sound arrived at station A at 11:00:00. It arrived at station B 2<sup>m</sup> 30<sup>s</sup> later. It arrived at station C 5<sup>m</sup> 00<sup>s</sup> later than at station A. Since these time differences and the velocity of sound in sea water are known, the added distances the sound traveled to get to stations B and C can be computed. The added distances b and c are found by multiplying the velocity of sound in sea water by the time differences.

Two circles are then constructed with points B and C, respectively, as centers. The radius of each circle is the added distance the sound travels to the point used as center. Finally, a circle is constructed so that it is tangent to circles B and C and passes through point A. The center of this circle is point P where the bomb was exploded.

The time of arrival of the sound must be recorded accurately to one-tenth of a second, if the fix is to be accu-

rate. The differences in arrival times in the example just considered were only a few minutes. Time differences up to one hour are possible. It has been assumed in this explanation that the earth is a plane surface.

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## QUIZ

1. Why is searchlight sonar unsatisfactory for locating underwater targets?
2. What are the two indications provided by scanning sonar?
3. Describe the transducer used with scanning sonar.
4. Why are the Doppler nullifier circuits necessary in the QHB-a?
5. In the QHB-a how is the frequency of the BFO corrected to remove the effect of Doppler?
6. What is the purpose of reverberation controlled gain (RCG) bias?
7. What is the purpose of a range recorder?
8. Upon what two things does the keying rate of the transmitter depend when used with the type CAN-55070 range recorder?
9. What is the effect on the stylus travel when the fly-back contact is moved to the right?
10. What type of hydrophone is used with the OAX?
11. What is the frequency range of the oscillator in the OAX?
12. How is OSC shown on a Mark 1 attack plotter?
13. What information is obtained from the QDA target depth determining equipment?
14. How does the function of the DDI differ from that of the BDI?
15. Why are more accurate target bearings obtained during ultrasonic listening?
16. Why is listening done chiefly on submarines?

17. Why is the transducer in ultrasonic echo-ranging equipment unsatisfactory for detecting sonic sounds?
18. What type of indication is provided by the master control unit of the JT?
19. When the hydrophone is trained to the left of a target what is the phase relation between the sum and difference signals at the output of the phase shifters in the JT?
20. What is the purpose of the sonar talkback system in the JT?
21. What is sofar?
22. In what way is sofar used to aid aircraft forced to make emergency landings at sea?
23. What comprises a sofar network?
24. Where is the hydrophone of a sofar station located?
25. What is recorded by the power-level recorder?

## RADIAC INSTRUMENTATION

### RADIATION

Radium, uranium, and the byproducts of atomic piles and atomic bomb explosions have the property of emitting certain types of invisible rays. The rays from radioactive substances can penetrate the human body, and sufficient exposure to these rays can result in injury or death. To protect personnel, equipment has been designed to detect the presence of these rays and to measure their intensity. The rays are of three types: alpha ( $\alpha$ ) rays, beta ( $\beta$ ) rays, and gamma ( $\gamma$ ) rays.

Alpha rays are streams of helium nuclei. Their power of penetration is small and they may be stopped by a thin sheet of some substance such as glass, mica, or clothing. The alpha rays have strong ionizing powers.

Beta rays are streams of high-speed electrons. Their penetrating power is approximately 100 times that of alpha rays. Beta rays may be stopped by a thin sheet of metal, and their ionizing power is less than that of alpha rays.

Gamma rays are very penetrating. They are electromagnetic waves similar to X rays. The penetrating power of gamma rays is 10,000 times as great as that of alpha rays. Thick walls of concrete or steel are needed to stop them. However, their ionizing power is much less than that of alpha rays.

The ionization produced by these rays while traveling through gases is perhaps the most convenient means of detecting them. The amount of ionization which takes place depends on the intensity of the rays.

The intensity of radiation produced by radioactive substances is measured in terms of a unit called the ROENTGEN. One roentgen is defined as the amount of radiation which produces  $2.85 \times 10^{10}$  ions in one cubic centimeter of air. A person can be exposed to 0.1 roentgen in a 24-hour period without ill effect. Radiac instruments are generally calibrated in milliroentgens since a roentgen is a large unit.

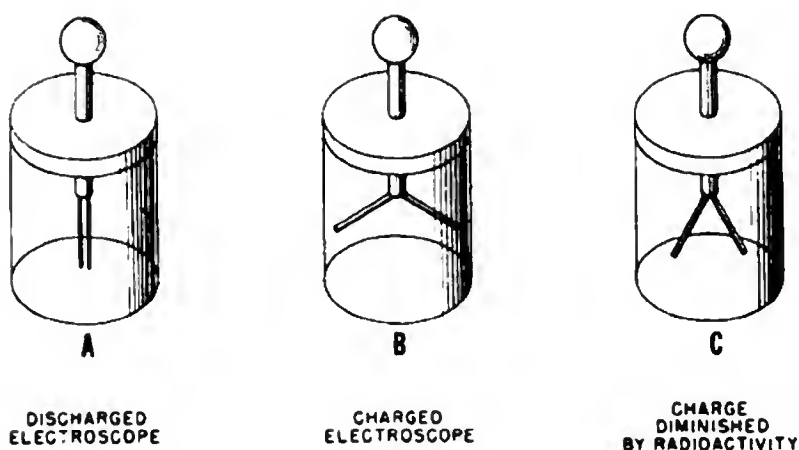
## RADIAC EQUIPMENT

The word "radiac" is derived from the first letters of the words "RAdioactivity Detection, Indication, And Computation." It is used to detect and measure the intensity of radioactivity. After an atomic explosion radiac equipment is used in surveying the area to determine safe and unsafe locations for personnel. Another important use is to monitor water supplies, food, clothing, vehicles, or personnel for possible contamination with radioactive materials. Radiac equipment is used by people who work with radioactive materials to determine the amount of radiation received by each individual.

## ELECTROSCOPE

A simple device for determining the presence of radiation is the ELECTROSCOPE (figure 16-1). In its usual form the electroscope consists of two pieces of gold leaf suspended side by side from the lower end of an insulated rod (figure 16-1,A). This type is known as the gold-leaf electroscope. The upper end of the rod terminates in a ball. The gold leaves are enclosed in a case made wholly or partly of glass, which protects the leaves from air cur-





**Figure 16-1.—Operation of a gold-leaf electroscope.**

rents and still permits observation of the movements of the gold leaves. The top of the container shown in figure 16-1 is electrically conductive.

The electroscope is charged like a capacitor. When a source of d-c potential is connected between the center rod and the top, the electroscope assumes a charge. The two pieces of gold leaf, having like charges, repel one another and diverge as shown in figure 16-1,B.

When the rays emitted from radioactive substances enter the chamber, some of the gas is ionized and a portion of the charge on the gold leaves is neutralized. The greater the ionization, the lower the charge on the leaves. Hence, the smaller force of repulsion makes the divergence of the leaves correspondingly less (figure 16-1,C).

### **RADIAC SET AN/PDR-3A**

Radiac set AN/PDR-3A consists of two units—a radiacmeter IM-9/PD and a radiac-detector charger PP-311A/PD. The radiacmeter is used to detect and measure gamma radiation. A photograph of the AN/PDR-3A appears in figure 16-2.

Radiacmeter IM-9/PD, commonly known as a DOSIMETER, is about the size of a fountain pen. It clips to the clothing of the wearer. This instrument indicates the total amount of gamma radiation to which it has been exposed since last charged.

The walls of the radiacmeter chamber are thick enough that alpha and beta radiation have no effect on the reading. The radiacmeter operates on the same principle as the gold-leaf electroscope. The charging potential is obtained from batteries contained in the detector charger.



Figure 16-2.—Radiac set AN, PDR-3A.

A cross-sectional view of the radiacmeter is shown in figure 16-3. In place of the gold leaf used in the electroscope, a metalized quartz fiber and a heavy wire support are substituted. The quartz fiber is capable of movement. Before it is used, the radiacmeter is charged by removing the dust cap and inserting the radiacmeter into the charging socket on the detector charger.

A small lamp in the detector charger shines through the radiacmeter so that the shadow of the quartz fiber falls on a scale in the radiacmeter. A potentiometer in series with the charging batteries is used to vary the

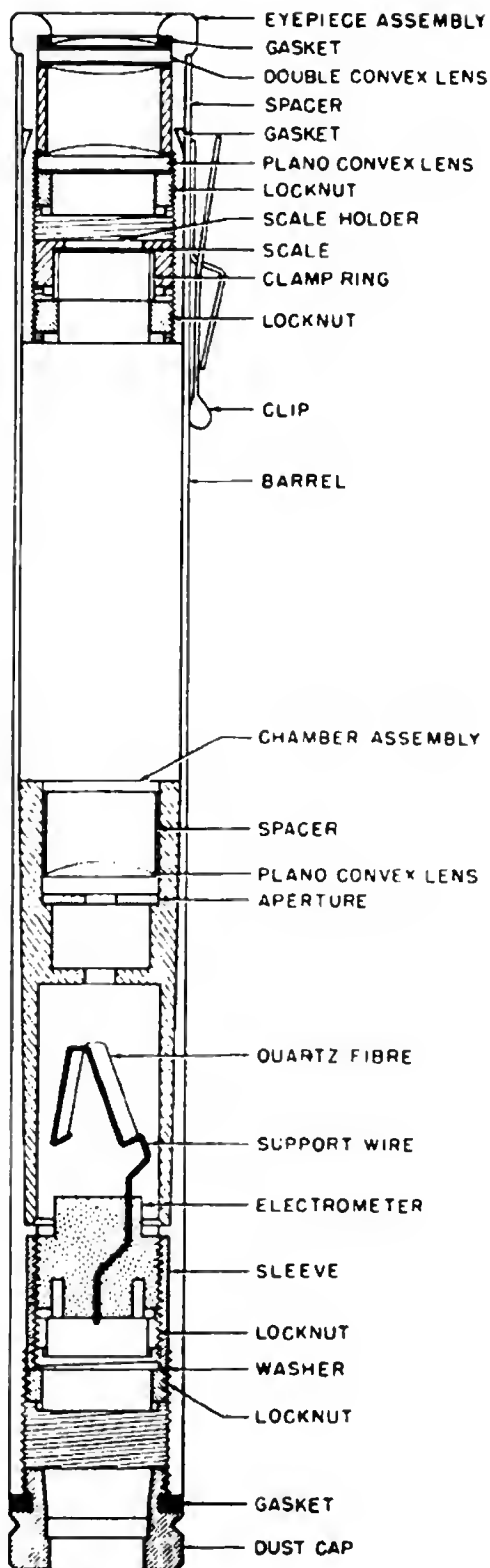


Figure 16-3.—Cross-sectional view of the radiacmeter IM-9 PD.

charge on the radiacmeter. The potentiometer is adjusted until the shadow of the quartz fiber falls on the zero mark of the scale. The support wire does not move because it is made of stiff wire.

An optical system in the radiacmeter magnifies the image of the scale so that it may be read easily. The scale is marked from 0 to 200 milliroentgens. The wearer can view the scale by removing the dust cap, holding the radiacmeter to the light, and looking through the eyepiece. The reading indicates the total amount of gamma radiation to which the radiacmeter has been exposed, but does not indicate the rate of exposure.

### **RADIACMETER IM-5/PD**

Radiacmeter IM-5/PD is a lightweight portable instrument designed to measure the rate of beta and gamma radiation. A photograph of it is shown in figure 16-4. This instrument measures from 0 to 5000 milliroentgens per hour. The IM-5/PD measures either the gamma radiation or the sum of the gamma and beta radiation.

The cylinder attached to the radiacmeter is the ionization chamber. On the end of this cylinder is a permanently attached nylon window. The nylon excludes alpha radiation, but does not stop the beta and gamma radiation. There is a rotary aluminum shield which may be placed across the entrance of the chamber to prevent beta radiation from entering the chamber. In this case the meter indicates only the gamma radiation.

The ionization chamber consists of a cylinder and an electrode placed along the axis of the cylinder. A voltage, obtained from dry batteries contained in the instrument, is maintained between the walls of the chamber and the center electrode. When beta or gamma rays enter the chamber, some of the gas molecules will be ionized. The positive ions will be attracted to the center electrode and the electrons will be attracted to the walls of the cylinder.

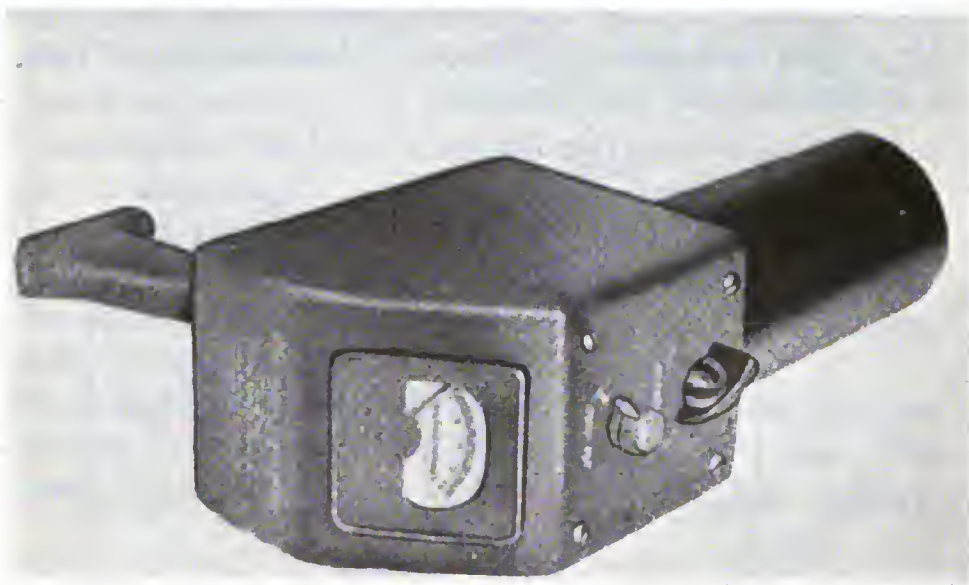


Figure 16-4.—IM-5/PD radiacmeter.

This constitutes a small current flow which upsets the balance of a bridge circuit. The ionization chamber current is proportional to the radiation dosage rate which is the radiation intensity per unit time.

A simplified schematic diagram of the IM-5/PD radiacmeter is shown in figure 16-5. The vacuum tube in the bridge circuit is specially designed for use in instruments of this type. The bridge is balanced when no radiation is present. Balancing is accomplished by turning potentiometer R108 to its midrange position and adjusting potentiometer R104 until the meter indicates zero. R108

is a screwdriver adjustment. The different ranges of the instrument are obtained by switching in different values of grid resistors.

Radiation entering the chamber causes a small ionization current to flow through the grid resistor. This lowers the bias and current through the tube increases, thus unbalancing the bridge. Current flows through the meter which indicates the rate of radiation. The meter reading is compared with a calibration chart attached to the side of the radiacmeter. The rate of ionization is found in milliroentgens per hour.

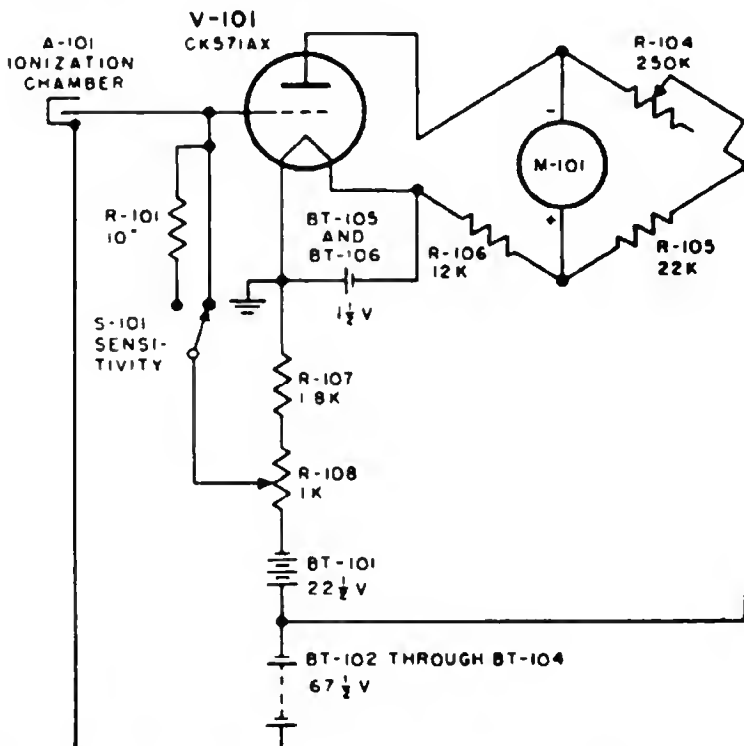


Figure 16-5.—Simplified schematic diagram of the IM-5 PD radiacmeter.

The IM-5/PD is useful for measuring high intensity radiation. The end of the chamber must be pointed toward the source of the beta radiation for accurate readings, because the beta rays will not penetrate the walls of the chamber. The ionization chamber has little direc-

tional effect for gamma radiation, since gamma rays penetrate the walls of the chamber.

## GEIGER-MULLER TUBE

The Geiger-Muller (G-M) tube is widely used for detecting alpha, beta, and gamma rays. One of the advantages of the G-M tube is the large amount of amplification which takes place in the ionization chamber itself. A typical G-M tube is shown in figure 16-6. The tube consists of a glass envelope, a cylindrical metal cathode, and an anode in the form of a piece of wire.

The tube is filled with a special mixture of gases. The anode is connected to a rather high positive potential (usually 800-1500 volts). The anode voltage is maintained slightly lower than that needed for continuous discharge of the tube. Therefore, in this condition, no steady current flows from the cathode to the anode.

When the tube is exposed to radiation, some of the gas molecules are ionized. The electrons ejected from the ionized molecules collide with other molecules causing

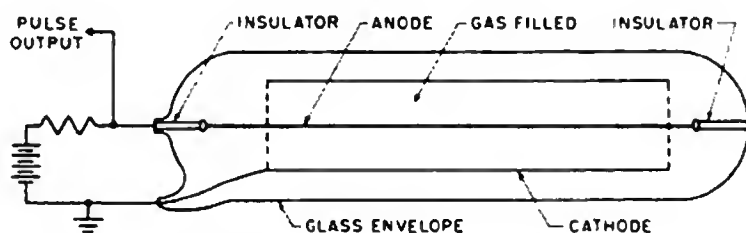


Figure 16-6.—Typical Geiger-Muller tube.

further ionization. In a short time practically all the gas is ionized. This process is called avalanche ionization. If measures are not taken to quench the process, a single ionization causes a continuous discharge of the tube, rendering it insensitive to further changes in radiation. The gas amplification of a G-M tube may be as high as  $10^8$  so that the pulses obtained require little amplification.

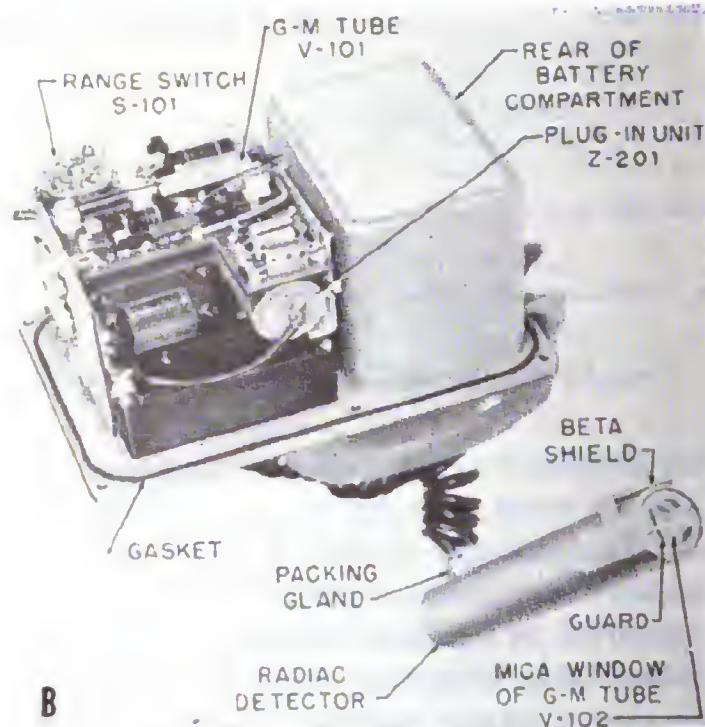
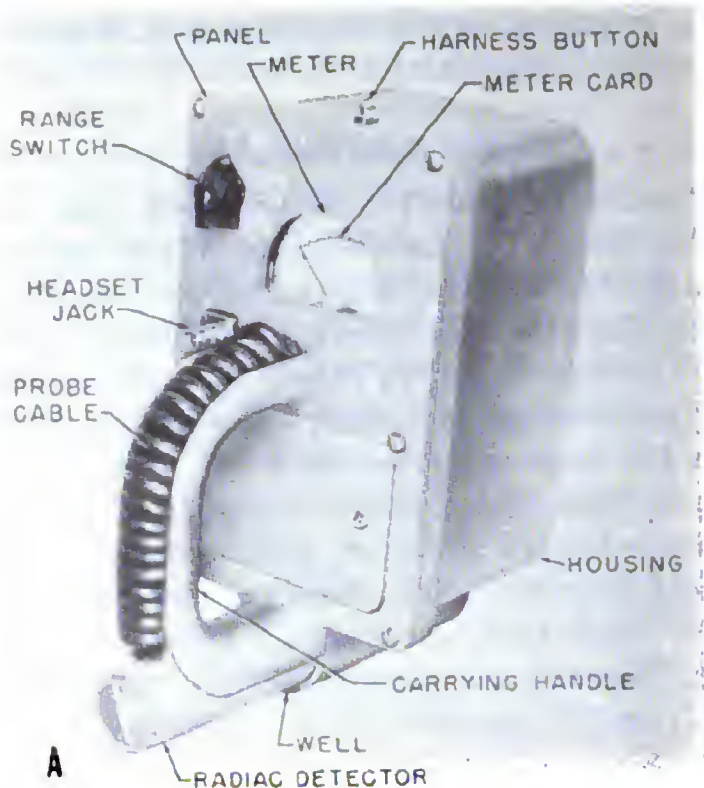


Figure 16-7.—IM-57/PDR-27 radiacmeter.



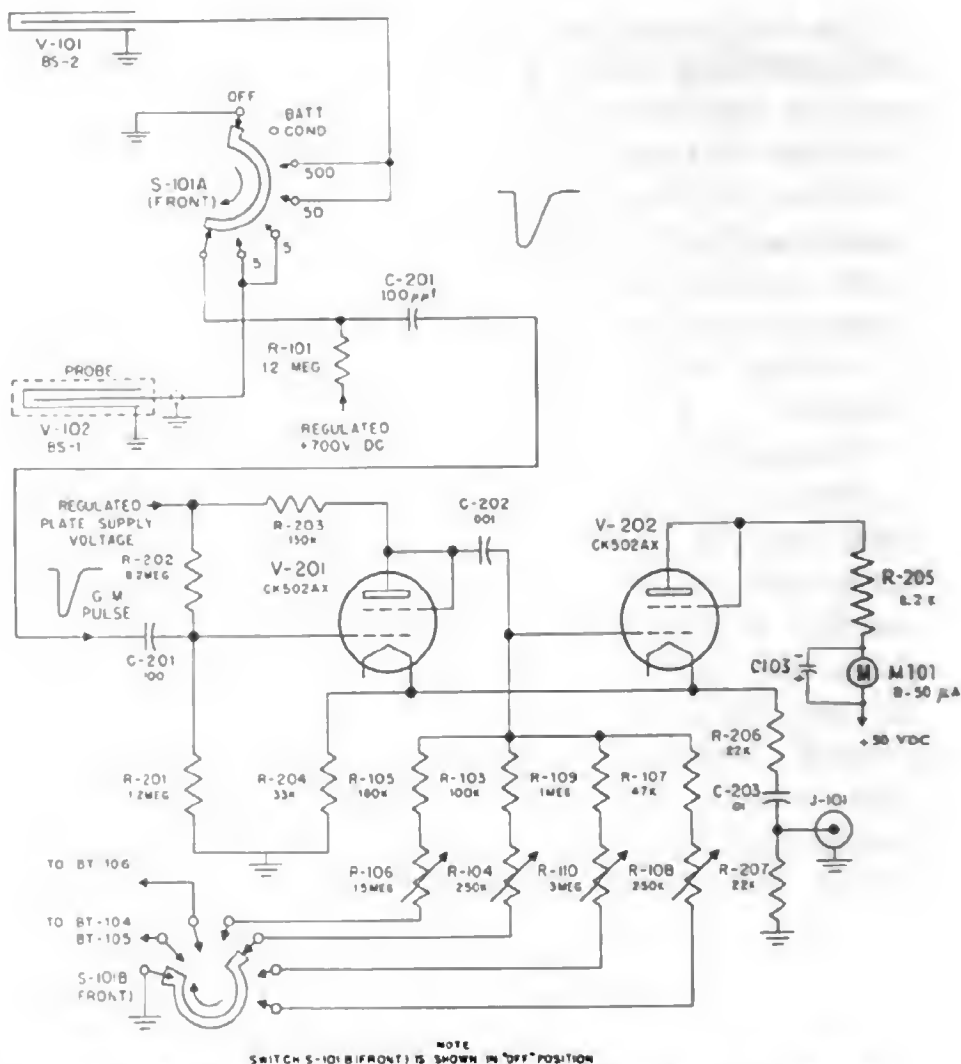
The G-M tubes used in Navy radiac equipment are the self-quenching type. A small amount of organic gas or vapor is introduced into the mixture of gases in the tube. This gas or vapor quickly stops or quenches the current resulting from ionization, so that each ionizing event causes only a short pulse of current. As soon as the tube stops conducting, it is ready for the next ionizing event. Since there are many ionizing events, the result is a series of voltage pulses appearing across the G-M tube load resistor.

The amplitude of the pulses from the tube might appear to depend on the energy and velocity of the radiation particles, but this is not necessarily true because of the large gas amplification in the tube. The pulses may be random as far as time is concerned, but each individual pulse has approximately the same amplitude irrespective of the intensity of the radiation. If the interval between arrival of particles is more than  $10^{-4}$  seconds, the particles can be counted in a properly quenched tube. This means that the number of pulses per unit of time, within limits, is a measure of the intensity of the radiation.

### **RADIAC SET AN/PDR-27**

Radiac set AN/PDR-27 is a portable battery-operated radiation detector and indicator. It may be used to detect and measure beta and gamma radiation together or gamma radiation alone. The main unit of this set is the IM-57/PDR-27 radiacmeter shown in figure 16-7. The radiacmeter uses two G-M tubes, one for measuring high intensity radiation, the other for measuring low intensity radiation.

One of the G-M tubes is housed inside the radiacmeter and is used to measure gamma radiation alone, since the case of the radiacmeter excludes beta radiation. The other G-M tube is contained in a probe and is connected to the radiacmeter through a cable. This tube can be used to



**Figure 16-8.—Simplified schematic diagram of the IM-57 PDR-27 radiacmeter.**

detect gamma radiation alone or both beta and gamma radiation, when the beta shield is removed. The probe also may be used in detecting beta radiation and low-intensity gamma radiation.

A simplified schematic diagram of the IM-57/PDR-27 radiacmeter is shown in figure 16-8. The output of the G-M tubes is a series of negative pulses which are coupled through a capacitor to the grid of V201. Tubes V201 and

V202 and their associated components form a one-shot multivibrator. Tube V201 is normally conducting. When a negative pulse is placed on the grid of V201, this tube cuts off and tube V202 conducts. The indicating meter in series with the plate of V202 indicates its average plate current.

The length of time that V202 conducts is governed by the time constant of capacitor C202 and the resistor selected by S101B. After C202 discharges sufficiently, V201 conducts and continues to do so until cut off by another negative pulse from the G-M tube. The rate of the pulses from the G-M tube and the frequency at which the multivibrator cycles depends on the number of ionization events in the G-M tube. These, in turn, depend on the intensity of the radiation.

Capacitor C103 shunts the meter, smooths out the current pulses of V202, and tends to keep the meter reading steady. Headphones may be connected to jack J101 so that the operator can hear the pulses from the G-M tube. The frequency of the pulses provide a rough indication of the radiation intensity. However, the indicating meter should be used for accurate readings.

## QUIZ

1. What types of rays are emitted by radioactive substances?
2. What is the most penetrating type of ray emitted from radioactive substances?
3. What is a convenient means of detecting the rays emitted from radioactive substances?
4. What is the purpose of radiac equipment?
5. What type of radiation affects the radiacmeter IM-9/PD?
6. What happens when radiation enters the ionization chamber of the IM-9/PD radiacmeter?

7. For what purpose is the G-M tube generally used?
8. What is the purpose of quenching a G-M tube?
9. How is a G-M tube made self-quenching?
10. What is the purpose of the two G-M tubes in the AN/PDR-27 radiac set?
11. What is the output of the G-M tubes in the IM-57/PDR-27 radiacmeter?

# APPENDIX I

## ANSWERS TO QUIZZES

### CHAPTER 1

#### RESPONSIBILITIES OF THE ET 2

1. Operations, Navigation, Gunnery, Engineer, Supply, and Medical.
2. The electrical assistant.
3. Parts that find application in only one type of equipment.
4. By referring to the latest Ship Electronic Installation Record submitted by that ship.
5. By a standard Navy stock number.
6. They are stowed in drawers and bins. The name and standard Navy stock number of the items stowed in a particular bin or drawer is indicated on that bin or drawer so that parts can be located easily.
7. To have replacements for parts that fail.
8. To obtain the exact materials and the correct quantity required.
9. The card is transferred with the equipment.
10. Without a record of field changes it would be difficult to determine what field changes had been made and consequently maintenance, trouble shooting, and ordering maintenance parts would be difficult.
11. In CEMB, RMB, or the *Sonar Bulletin*.
12. The Repair Record Card, the Alteration Record Card, and the Record of Field Changes.
13. The change can be reported by filling in the top part of an Electronics Failure Report and writing the number of the field change under the space for remarks.
14. He should examine the tubes for breakage, rough handling, and defective packing. Electrical tests should be conducted if possible.

15. *The Electronics Maintenance Book.*
16. To the nearest district publications and printing office.
17. *The U. S. Navy Regulations* and the *Registered Publications Manual.*
18. *The Security Classification of Electronics Equipment (JANAP 140(A)).*
19. The official Bureau of Ships' allowance of electronic equipment for all types and classes of naval vessels.

## CHAPTER 2

### TEST EQUIPMENT—MEASUREMENT

1. The full-scale deflection current and the voltage range desired.
2. In ohms per volt.
3. By connecting shunts in parallel with the moving coil.
4. Because it loads the circuit and introduces objectionable error.
5. (1) Voltages at high frequencies can be measured, and (2) the current drawn from the circuit under test is usually negligible.
6. (1) The emission tester, and (2) the dynamic mutual conductance tester.
7. 
$$g_m = \frac{\Delta I_p}{\Delta E_g}$$
8. The B-supply voltage of the tester.
9. It serves as a fuse to protect the instrument from excessive overload.
10. They complete a circuit that applies the a-c voltage across a resistor of the neon SHORTS lamp through a coupling capacitor and shunt resistor.
11. Reversed grid current reduces the bias and increases plate current.
12. Because the currents in the two halves of  $R$  are equal and opposite on alternate half cycles and the inertia of the moving parts of the meter prevents the meter following the power line frequency.

13. Because on one alternation P2 is positive when the a-c signal voltage is positive and plate current increases through the upper half of  $R$  and on the next alternation P1 is positive when the signal voltage is negative and plate current through the lower half of  $R$  decreases. The unbalance is sustained on successive alternations and the meter indicates the amount.

## CHAPTER 3

### TEST EQUIPMENT—ANALYSIS

1. To provide a visual means of examining waveforms encountered in electric circuits.
2. Filament, cathode, control grid, first anode, and second anode.
3. By two pairs of deflection plates. The test signal may be applied across one pair at the same time a saw-tooth or sweep-frequency voltage is applied across the other pair.
4. The distance that the electron beam is moved across the screen by a change of 1 volt across the deflection plates.
5. To remove secondary electrons emitted from the fluorescent screen.
6. The output frequency is not stable and its range is limited by the time required to deionize the gas.
7. The beat-frequency type and the resistance-capacity type.
8. The lamp acts as an automatic amplitude limiter to keep the amplitude of the oscillations constant.
9. The extreme accuracy of calibration and stability that is present in a frequency meter is usually not found in a signal generator.
10. The crystal oscillator is much more accurate than the heterodyne oscillator and is used to calibrate the heterodyne oscillator.
11. To ensure that the comparison crystal in the frequency meter is still reliable.
12. A portable radio receiver with output meter to indicate strength of received signal.
13. (1) Locating sources of signals that violate radio silence, (2) locating sources of signals that interfere with radio receiving equipment, (3) checking the effectiveness of measures for eliminating interference, and (4) adjusting directional antenna arrays.

14. 2.5 to 100,000 microvolts without the attenuator, and 10,000 to 100,000 microvolts with the attenuator.

## CHAPTER 4

# LOW- AND MEDIUM-FREQUENCY RADIO TRANSMITTERS

1. A way of sending messages with a radio transmitter that interrupts the carrier with a key to send dots and dashes.
2. Continuous wave transmission in which the carrier is modulated with an audio signal of about 800 cycles.
3. A system of sending messages with a radio transmitter which replaces the operator for changing plain language into code and code into plain language. The operator presses keys on a keyboard similar to a typewriter and the received signal at the other end of the transmission is typed out on paper.
4. A period of emission from the transmitter represents a mark and a period of no emission represents a space.
5. Shifting the frequency of the transmitter 425 cycles above and below the center frequency to correspond to marks and spaces.
6. The carrier is amplitude modulated with two audio tones, usually a 500-cycle tone for a space and 700-cycle tone for a mark.
7. By placing the frequency determining components of the oscillator in a temperature controlled oven, loading the oscillator lightly, isolating the oscillator by use of a buffer stage, and shock mounting the oscillator unit.
8. The electron-coupled oscillator tends to be more stable than other types of oscillators.
9. This method of operation reduces interaction between the plate and grid circuits and improves oscillator stability.
10. The motor-generator would become energized as soon as S331 were closed. If the stop button, S40A, were depressed and held in that position the motor would stop, but would start again as soon as the stop button were released.



11. No. It is necessary to pull the main bulkhead switch and preferably to pull the main fuses before servicing the TBL transmitter.
12. The system provides protection against damage caused by bias-supply failure. If the high-voltage generator were self-excited and the bias supply became inoperative the amplifier tubes would be damaged or destroyed because they would conduct heavily as a result of the bias loss. With the system used in the TBL the loss of bias also results in loss of high voltage.
13.  $\frac{13,476}{12} = 1123 \text{ kc.}$
14. (a) The grid current of the final amplifier drops. (b) Opening the switch removes the short around R21 and introduces additional grid resistance in the final amplifier. This action increases grid bias and lowers grid current.
15. No m-c-w operation could be obtained.
16. Frequencies between 9050 kc and 18,100 kc.
17. The second intermediate power amplifier.
18. The TBL uses a keying relay to open and close the circuit between filament transformer center tap and ground and thus control cathode currents in the oscillator and first and second amplifiers. The TBM varies the screen voltage of the oscillator tube to turn the transmitter off and on.
19. The compressor-limiter of the modulator unit. If the audio level increases above a certain predetermined level, additional bias is developed and applied to the speech amplifiers to keep the audio level constant.
20. A counterpoise is constructed above ground and a ground radial is buried beneath the surface.
21. The sandy soil has a very high resistance. Because the earth functions as a part of the antenna, much of the energy would be dissipated by  $I^2R$  losses in the earth instead of being radiated.
22. Normally the center frequency is *not* transmitted. The keyer allows a frequency of either 425 cycles above the carrier or 425 cycles below the carrier to be transmitted.

23. S3 is a multiplication factor switch that reduces the amount of frequency shift of the 200-kc oscillator by reducing the positive bias on the reactance tube. This action is necessary in case the output frequency of the FSB keyer is to be multiplied.

## CHAPTER 5

### V-H-F AND U-H-F TRANSMITTERS

1. (a) No. (b) At times ultra-high frequencies are refracted and can be received at great distances.
2. 300 Mc to 3000 Mc.
3. The phenomenon by which horizontal layers in the atmosphere act like ducts or waveguides in which the u-h-f waves may travel far beyond the horizon.
4. 7.4 Mc.
5. 225 Mc to 400 Mc.
6. Voice modulation or m-c-w.
7. 10.
8. Frequencies can be selected easily and rapidly by inexperienced personnel using a telephone-type dial.
9. A modified electron coupled Colpitts circuit with the crystal replacing the grid tank inductance.
10. Oppositely. Plate voltage increase causes oscillator frequency to decrease and screen voltage increase causes oscillator frequency to increase.
11. The grounded grid effectively shields the plate from the cathode, reducing the grid-to-plate capacity.
12. (a) The carbon button type of microphone. (b) Because of the 12-volt d-c polarizing voltage in the input circuit.
13. To provide a sample of the modulator output which allows monitoring of the audio signal.
14. (a) Yes. (b) Because the modulators operate class-B and require that the driving tube be able to supply power.
15. (1) It matches the side-tone secondary of the modulation transformer to the transmission line and (2) it allows the attenuation of the signal without upsetting the impedance match.

16. An automatic gain control circuit is incorporated in the audio amplifier of the modulator to reduce the gain of the system when the input exceeds a certain preset value.
17. 95 percent.
18. V107 and V108.
19. Taps are provided on the transformers to raise the voltages applied to the rectifiers as their resistance increases with age.

## CHAPTER 6

### LOW FREQUENCY COMMUNICATION RECEIVERS

1. L-f band.
2. In the superheterodyne the incoming signal is heterodyned to produce an intermediate frequency which is lower than the incoming frequency.
3. To allow a leakage path for static charges that accumulate on the antenna.
4. To protect the input circuit against excessive voltage.
5. By variation of the amount of fixed bias on the grids of the r-f stages, as well as the first audio stage.
6. Rheostat R128 is geared to the main tuning control and automatically increases the bias on first and second r-f stages to lower the sensitivity as the receiver is tuned to higher frequencies.
7. About 15 volts.
8. The low voltages on this amplifier stage cause it to act as a limiter for strong signals, but it still gives some amplification for weak signals.
9. An oscillator signal whose frequency is 1000 cycles above the incoming c-w signals is beat with the received signals in the detector to produce an audio signal in the detector output.
10. With S103 in the BROAD position a low-pass filter passes frequencies up to 1300 cycles and attenuates frequencies above this value. With S103 in the SHARP position a band-pass filter passes only a band of frequencies between 850 and 1150 cycles.

11. With S104 in the ON position the plate and screen voltages may be adjusted by R137 so that the output of the receiver can be held constant.
12. To prevent stray r-f energy from entering the receiver through the headphone cord.
13. With no load or light load across the secondary winding a maximum negative feedback voltage is applied to the second and third audio stages and the gain of these amplifier stages is reduced. If more load is placed across the output winding, more current flows, causing the output voltage to decrease. Thus a smaller negative feedback voltage allows the gain of the two stages to increase and a substantially constant output voltage is obtained.
14. 6560 feet.
15. High frequency permits the use of small directional antennas, which can be easily rotated.
16. (a) No. (b) Because ground losses are rather high and efficiency is too low.
17. By arranging several of the antennas in a simple array.

## CHAPTER 7

### MEDIUM- AND HIGH-FREQUENCY COMMUNICATION RECEIVERS AND ANTENNA SYSTEMS

1. About 30 miles.
2. The upper portion of the medium-frequency band and all of the high-frequency band.
3. Either a whip or a long wire.
4. Between 5 and 30 Mc.
5. About 800 ohms.
6. I-f amplifiers, c-w oscillator, silencer, noise limiter, second detector, and audio amplifiers.
7. Antenna circuit, local oscillator, mixer, and r-f amplifiers.
8. A small gas tube is placed across the tank. If high r-f voltages are developed in the antenna circuit of the receiver, the tube ionizes and shorts the voltage to ground.

9. To reduce the capacity of the oscillator tuning capacitor and make it tune 400 kc below the frequency to which the r-f stages are tuned.
10. By altering the coupling between the primary and secondary windings of the i-f transformers.
11. The third i-f stage does not have a-v-c voltage applied to it.
12. (a) No. (b) If the noise pulse were clipped to a point below the audio level, the audio would also be clipped because the limiter is in series with the audio output.
13. The output level controls the level of the audio signal; the gain control varies the amplification of the i-f stages.
14. The strength of the a-v-c voltage, which is proportional to the received carrier strength.
15. A cathode follower has a high input impedance and a low output impedance.
16. Zero.
17. By changing the position of switch S102.
18. V203 tends to be cut off.
19. Frequency modulation.
20. 27.0 to 38.9 Mc.

## CHAPTER 8

### V-H-F AND U-H-F RECEIVERS

1. 230.6 to 389.8 Mc, or approximately 200 to 400 Mc.
2. By employing a crystal controlled oscillator and four frequency multiplier stages.
3. 27.8 to 143 Mc.
4. The r-f amplifier, mixer, local oscillator, first two i-f stages, and the audio amplifiers.
5. A diode detector for a-m reception and a discriminator for f-m reception.
6. They are shorted to ground.
7. A small inductor and resistor inserted in the secondary of each i-f transformer increase the coupling and lower the  $Q$  of the circuits.

8. By decreasing cathode bias on last i-f stage as bandwidth is increased on preceding stages.
9. Bandwidth increases with coupling; gain decreases.
10. By a special d-c 150-0-50 microampere meter in the plate circuit of the third i-f amplifier stage. Increased signal strength and a-v-c bias decrease plate current and cause the meter needle to deflect toward the right-hand of the scale.
11. It is connected across the output of the discriminator.
12. The meter indicates first on one side of zero and then on the other as the receiver is tuned through the signal. Correct tuning is indicated when the meter pointer is at zero.
13. They form a de-emphasis circuit which reduces high-frequency components introduced at the f-m transmitter.
14. The capacitors have split stators with the associated rotors in series.
15. The coil and the two sections of the capacitor form a balanced bridge in which the r-f voltage between the center tap of the coil and the corresponding midpoint of the capacitor is zero. Grounding the coil at the center tap effectively grounds the capacitor rotor at its midpoint.
16. To raise the resonant frequency of the wave trap that is formed by the r-f ground to a value above the tuning range of the receiver.
17. To avoid the possibility of having the 15-Mc i-f stages blocked by a third harmonic of the crystal that would be used in the converter for the 222- to 232-Mc range.
18. Either 48 or 64 times.
19. The tuned circuit in the plate circuit of the mixer.
20. By tuning for maximum deflection on the input meter which indicates the grid-leak bias on the multiplier stages.
21. By varying the coupling between primary and secondary windings of the i-f transformers in these stages.
22. Five.
23. Powdered iron slugs in the primary and secondary of the i-f transformers can be moved in or out by screw-driver adjustment.

4. By a series noise limiter in the output of the diode detector. The diode normally conducts, but a sudden burst of noise makes the plate negative with respect to the cathode and conduction ceases, thus interrupting the detector output.
15. To disable the receiver during periods when no signal is being received.
16. To keep the audio output of the receiver constant as the load changes across the output transformer.

## CHAPTER 9

### RADIO DIRECTION FINDERS

1. A sensitive receiver and a directional antenna.
2. In the low and medium frequency bands.
3. Because the ground wave has a definite vertical polarization whereas a sky wave has a shifting polarization which will introduce errors in the RDF bearings obtained.
4. (1) Electric field, and (2) magnetic field.
5. Vertically.
6. The magnetic field.
7. By providing a metallic shield around the loop.
8. The segment prevents the shield from acting as a shorted turn.
9. Small.
10. The plane of the loop is parallel to the direction of travel of the wave.
11. The induced voltage lags the magnetic field component by  $90^\circ$ .
12. Bidirectional.
13. An induced voltage in the vertical sides of the loop acting as simple vertical antennas.
14. Spurious voltages in the loop caused by reradiation of the signal by metallic objects in the proximity of the loop.
15. By placing the RDF loop inside a large compensating loop.
16. They are in phase opposition.
17. A change in the polarization of the radio wave due to refraction in the ionosphere, resulting in deviation error.
18. A unilateral pattern.

19. The differential loop voltage is displaced  $90^\circ$  from the voltage induced in the vertical antenna.
20. The two voltages are displaced  $90^\circ$ .
21. They are either in phase or  $180^\circ$  out of phase.
22. The coupling transformer has a tuned primary and a tuned secondary.
23. To determine the type of modulation, pulse width, and speed of rotation of the antenna in radar installations.
24. (1) Night effect is eliminated. (2) The antenna has a unilateral pattern. (3) Quadrature effect is eliminated.
25. It acts as a 1-to-1 transformer having a balanced primary and an unbalanced secondary, thus permitting a coaxial line feed without grounding one side of the antenna.
26. To amplify the output of the receiver and display the received signals on a cathode-ray tube.
27. The pattern on the cathode-ray screen points on the same bearing as the antenna.
28. To prevent positive signals from affecting the deflection of the beam in the cathode-ray indicator.
29. The spaces are proportional to the PRF.

## CHAPTER 10

### LORAN TRANSMITTING EQUIPMENT

1. To obtain navigational fixes.
2. Because at night, sky waves can be used.
3. (1) Loran may be used as well in a heavy fog as in clear weather. (2) Loran fixes can be made rapidly. (3) Loran fixes can be made any time of the day or night.
4. The master station.
5. Absolute delay.
6. At the slave station.
7. By having a double-pulsed master station that transmits two distinct sets of pulses—one set at the PRR of one slave and the other set at the PRR of the other slave.
8. Four.



9. By operating different pairs of stations on different pulse recurrence rates.
10. Seven.
11. The lines of position of different pairs are printed in different colors.
12. When the transmitter is double-pulsed.
13. Tuned-plate tuned-grid.
14. To limit the current drawn from the power supply when the oscillator is pulsed.
15. By a 100-kc crystal oscillator and a series of counting circuits that divide the 100-kc signal to obtain the pulse repetition rate.
16. An automatic blinking circuit causes the pulses seen on a loran indicator to have a characteristic movement that warns the operator not to use this particular pair of stations to get a fix.
17. To prevent any external fields from disturbing the timers.
18. All cables either entering or leaving the shielded room.
19. It roughly balances the signal from the remote station and the local station.

## CHAPTER 11

### LORAN RECEIVING EQUIPMENT

1. As pulses on a cathode-ray tube.
2. To reject signals on or near the intermediate frequency of the receiver.
3. A Colpitts oscillator.
4. To the vertical deflection plates of the cathode-ray tube in the indicator.
5. To measure the time difference between a pulse from the master station and a pulse from a slave station operating on the same PRR.
6. The delay controls must not be disturbed until the time difference is read.
7. By a series of counter circuits which divide the 100-kc signal of the standard frequency generator.

8. To vary the frequency of the standard frequency generator to bring it into synchronism with the loran transmitting stations.
9. By driving it into cutoff and saturation with the sine-wave output of the standard frequency generator.
10. More input pulses would be required for one output pulse. The number of input pulses depends on this bias.
11. The square-wave generator and slow-sweep generator circuits.
12. An Eccles-Jordan multivibrator.
13. The time-delay circuits.
14. The *A*-delay is fixed and the *B*-delay is variable.
15. To the horizontal deflection plates of the cathode-ray tube.
16. To provide a small amount of negative feedback and yet keep the output at a moderately high impedance.
17. Because adjusting the gain control affects both signals simultaneously.
18. The amount the arm is displaced from the center position.
19. By adjusting potentiometer R231 which adjusts the bias on the control tube V131.
20. It increases, counteracting the increase at the regulated bus.

## CHAPTER 12

### SYNCHROS

1. A self-synchronous a-c machine that is used to transmit angular motion from one location to another.
2. They are wye-connected.
3. When the rotors of the two units are in correspondence—that is, when the voltages induced in corresponding windings of the stators are equal and opposed to each other.
4. The windings consist of three groups of coils the axes of which are 120 mechanical degrees apart.
5. S1, S2, and S3.
6. Only the receiver rotor has an inertia damper.
7. 52 volts (rms).

8. Because the rotor has a greater number of turns to compensate for losses, and this compensation would not be correct if the rotor became the primary.
9. To compare the angular positions of two devices in a servo system by means of an error signal.
10. By the transformer action from the stator.
11. Because the shaft is turned directly or indirectly by the load.
12. No voltage is induced in the rotor. This is the electrical zero position.
13. To reduce the current in a synchro transmitter by improving the power factor of the load circuit.
14. As close as possible to the control transformer or differential unit the power factor of which is to be improved.

## CHAPTER 13

### BASIC PRINCIPLES OF SONAR

1. By disabling the transmitter.
2. Solids, liquids, and gases.
3.  $c = \lambda f$ .
4. The velocity of sound in air is proportional to the temperature and increases about 2 feet per second for each degree centigrade increase.
5. Reflections from the surface of the water, from the bottom of the body of water, and from air bubbles and foreign matter in the water.
6. The loss of energy as the sound waves travel through water.
7. Because the temperature of the water changes with depth and causes the beam to be refracted.
8. A condition in which the temperature of the water decreases with depth.
9. It is a relatively thick layer of water that has a constant temperature.
10. An instrument that measures the temperature at different depths and automatically draws a graph of temperature as compared to depth.

11. (1) Amplified noise which comes in through the electronic system, and (2) airborne noise picked up in the sonar operator's space.
12. Because of the lower noise level on a submarine.
13. The property of certain substances to change their dimensions when they are magnetized.
14. The property that some crystalline substances have of generating a voltage between opposite faces of the crystal as a result of strain due to pressure or twist.
15. To determine whether a target is moving toward or away from an observer or not moving at all.
16. To eliminate the effect of own ship movement.
17. To determine the depth of the water.
18. By listening to the returning echoes and noting the position of the white lamp on the dial when the echo from the bottom is heard.
19. By a half-speed eccentric.
20. By beating the output of two crystal oscillators in a mixer.
21. A superheterodyne receiver.

## CHAPTER 14

### SEARCHLIGHT SONAR SYSTEMS

1. A system in which a directional projector is used to concentrate the outgoing pulse of sound energy into a narrow beam, thus "illuminating" the target like a searchlight. The directional projector also provides a directional pattern for receiving.
2. A transmitter, a receiver, and a transducer.
3. During the time a pulse is transmitted.
4. A relay or other device disconnects the transducer from the transmitter and connects it to the receiver input.
5. By training the projector to a position in which the maximum echo is received.
6. They are the same.

7. The directivity of the transducer, which depends on the narrowness of the sound beam.
8. The long time it takes to search the area around a vessel.
9. They are raised and lowered with the hoist-train mechanism.
10. When the equipment is first turned on, both the signal-on and signal-off tube may be conducting at the same time. Pressing the keying interrupter allows the signal-off tube to assume control.
11. By removing cutoff bias from the master oscillator with a relay.
12. To aid the operator in training the transducer exactly on the target.
13. When the input to the left r-f converter tube and the input to the right r-f converter tube are equal.
14. By noting the position on the sweep where the echo appears.
15. To the loudspeaker and the range recorder.
16. When the magnetic clutch is energized.
17. The clutch is energized when the keyer tube conducts. The magnetic clutch coil is in the keyer tube plate circuit.
18. To provide a protective shell for the transducer. The dome is also shaped to minimize turbulence around the projector.
19. The brake-release switch must be turned off.
20. By opening one side of the relay control circuit which then deenergizes all of the relays. When the three-phase brake coil is deenergized, a mechanical brake is applied to the hoist-lower motor.

## CHAPTER 15

### SONAR AND LISTENING EQUIPMENT

1. Because of the limited sector covered by the relatively narrow sound beam and the time consumed between transmissions.
2. (1) A continuous visual display of acoustic reception from all directions, and (2) an audio response from any desired single direction.
3. It is composed of a large number of small magnetostriction units (or crystals) arranged in a circle.

4. Because of the sharp response of the audio circuits.
5. A discriminator controls two reactance tubes which shift the frequency of the BFO.
6. To lower the receiver gain after the transmitted pulse and gradually restore the gain to normal as the amplitude of the reverberations decreases.
7. To record graphically the echoes received by sonar equipment.
8. The setting of the fly-back contact and the discharge of a 6- $\mu$ f capacitor through the relay coil in series with a 10,000-ohm resistor.
9. The stylus travel is lengthened.
10. A magnetostriction hydrophone.
11. 17 to 26 kc.
12. By a succession of bright spots.
13. Sound range and depression angle.
14. The DDI indicates errors in depression rather than errors in azimuth.
15. Because for a given hydrophone the directivity pattern becomes sharper for ultrasonic listening.
16. Because a submarine makes only a small amount of sound. Thus surface vessels can be detected more easily from a submarine.
17. Usually the receiver does not tune to a frequency low enough to detect these sounds and the frequency range of the transducer is limited and does not extend into the sonic range.
18. It gives a left-right indication on a meter.
19. They are 180° out of phase.
20. To provide communication between the operator and the conning tower. Also audio signals from the JT can be connected to this system so that personnel in the conning tower can hear them.
21. A means of receiving an underwater sound signal (usually initiated by a bomb) and locating its source.
22. To fix their positions.

23. Several widely separated shore-based listening stations. Each station has listening equipment connected to a hydrophone.
24. In the ocean near the center of a sound channel.
25. Arrival time of the sound from a sofar bomb and the amplitude of this sound.

## CHAPTER 16

### RADIAC INSTRUMENTATION

1. Alpha, beta, and gamma rays.
2. Gamma rays.
3. By the ionization produced when these rays travel through gases.
4. To detect and measure the intensity of radio activity.
5. Gamma radiation.
6. Some of the gas molecules are ionized and a small current flows. This action unbalances a bridge circuit and provides an indication on a meter.
7. To detect alpha, beta, and gamma rays.
8. To prevent a continuous discharge of the tube after an ionization event from rendering the tube insensitive to further changes in radiation.
9. By introducing a small amount of organic gas or vapor into the mixture of gases in the G-M tube.
10. One is used to measure high-intensity radiation; the other is used to measure low-intensity radiation.
11. A series of negative pulses.





## APPENDIX II

# QUALIFICATIONS FOR ADVANCEMENT IN RATING

## ELECTRONICS TECHNICIANS (ET)

JOB CODES ET-1500 TO ET-1599

RATING CODE NO. 1000

### General Service Rating

Electronics technicians maintain, repair, calibrate, tune, and adjust all electronic equipment (except aircraft and ordnance electronic equipment) used for communications, detection, ranging, and countermeasures.

### Emergency Service Ratings

Title	Abbr.	Definition
Electronics Technicians N. (Communications) Rating Code No. 1001.	ETN	Perform technical maintenance and repair on radio communication equipment including radio receivers and transmitters, Loran and direction finders, remote control, display and recording, communication countermeasure, infrared, and automatic communication equipment.
Electronics Technicians R. (Radar) Rating Code No. 1002.	ETR	Perform technical maintenance and repair on radar equipment (except aircraft) including search radar, remote control, display, electronic identification, radar countermeasure, radar switchboard, and control equipment.
Electronics Technicians S. (Sonar) Rating Code No. 1003.	ETS	Perform technical maintenance and repair on sonar equipment including echo ranging, depth finding, remote control, display, resolving and recording, attack director, sonar countermeasure, and bathythermograph equipment.

## Navy Job Classifications and Codes

For specific Navy job classifications included within this rating and the applicable job codes, see *Manual of Enlisted Navy Job Classifications*, NavPers 15105 (Revised), codes ET-1500 to ET-1599.

### Qualifications for Advancement in Rating

Qualifications for Advancement in Rating	Applicable Rates			
	ET	ETN	ETR	ETS
<b>XXX. 100 PRACTICAL FACTORS</b>				
<b>101 OPERATIONAL</b>				
1. Demonstrate method of resuscitating a man unconscious from electrical shock and treating for electrical burns.....	3	3	3	3
2. Send and receive International Morse Code Alphabet.....	3	3	3	3
3. Start, stop, calibrate, and tune the following in own ship or station:				
a. Radio equipment.....	3	3		
b. Radar equipment.....	3		3	
c. Sonar equipment.....	3			3
4. Operate emergency and portable power supply equipment, including internal combustion engines (both gas and Diesel) used in connection with electronic equipment.....	2	2	2	2
<b>102 MAINTENANCE AND/OR REPAIR</b>				
1. Observe safety precautions in installation, operation, and repair of electronic equipment.....	3	3	3	3
2. Use and maintain hand tools and operate small portable power tools in electronic installation and repair.....	3	3	3	3
3. Use test equipment in electronic service work.....	3	3	3	3

## Qualifications for Advancement in Rating—Contd

Qualifications for Advancement in Rating	Applicable Rates			
	ET	ETN	ETR	ETS
4. Locate leaks and make emergency repairs on pressurized transmission lines in own ship or station.....	3	3	3	3
5. Draw and interpret schematic diagrams of electronic circuits; read and interpret electronic wiring and circuit diagrams found in manufacturers' instruction books.....	3	3	3	3
6. Locate shorts and grounds, and effect emergency repairs on pressurized and coaxial-type transmission lines.....	3	3	3	
7. Locate and identify component parts by reference to the associated circuit diagrams for the following on own ship or station:				
a. Radio equipment.....	3	3		
b. Radar equipment.....	3		3	
c. Sonar equipment.....	3			3
8. Locate and identify individual units of electric and electronic remote control systems associated with the following in own ship or station:				
a. Radio equipment.....	3	3		
b. Radar equipment.....	3		3	
c. Sonar equipment.....	3			3
9. Locate and identify the main, emergency, and casualty power supply systems in own ship or station for:				
a. Radio equipment.....	3	3		
b. Radar equipment.....	3		3	
c. Sonar equipment.....	3			3
10. Perform preventive maintenance and under close supervision, perform casualty analysis and repairs to:				
a. Radio equipment.....	3	3		
b. Radar equipment.....	3		3	
c. Sonar equipment.....	3			3
d. Radiac equipment.....	3	3	3	3

## Qualifications for Advancement in Rating—Contd.

Qualifications for Advancement in Rating	Applicable Rates			
	ET	ETN	ETR	ETS
11. Maintain and repair motor generators, starting panels, motor controllers, and "start-stop" equipment associated with electronic equipment on own ship or station.....	2	2	2	2
12. Perform maintenance and repair on emergency and portable supply equipment including internal combustion engines (both gas and Diesel) used in connection with electronic equipment.....	2	2	2	2
13. Perform technical maintenance (internal tuning and adjustments) to the following in own ship or station:				
a. Radio equipment.....	2	2	-----	-----
b. Radar equipment.....	2	-----	2	-----
c. Sonar equipment.....	2	-----	-----	2
d. Radiac equipment.....	2	2	2	2
14. Make sensitivity and selectivity measurements and corrective adjustments for the following on own ship or station:				
a. Radio equipment.....	2	2	-----	-----
b. Radar equipment.....	2	-----	2	-----
c. Sonar equipment.....	2	-----	-----	2
15. Measure accuracy of and calibrate in own ship or station:				
a. Radio equipment.....	2	2	-----	-----
b. Radar equipment.....	2	-----	2	-----
c. Sonar equipment.....	2	-----	-----	2
16. Maintain and repair electronic test equipment:				
a. Nonprecision.....	2	2	2	2
b. Precision.....	1	1	1	1
17. Effect permanent repairs to pressurized and coaxial-type transmission lines.....	1	1	1	-----

## Qualifications for Advancement in Rating—Contd.

Qualifications for Advancement in Rating	Applicable Rates			
	ET	ETN	ETR	ETS
18. Make complete casualty analyses, and effect repairs within the capabilities of own ship or station to:				
a. Radio equipment.....	1	1	-----	-----
b. Radar equipment.....	1	-----	1	-----
c. Sonar equipment.....	1	-----	-----	1
19. Design and install shore station type resonant and nonresonant transmission lines, including use of metallic insulators.	C	C	C	-----
<b>103 ADMINISTRATIVE AND/OR CLERICAL</b>				
1. Use manufacturers' instruction books furnished with equipment and technical maintenance bulletins.....	3	3	3	3
2. Procure, stow, and account for electronic stores and spare parts.....	2	2	2	2
3. Maintain electronic equipment histories. Prepare job orders and work requisitions.	2	2	2	2
4. Supervise and train personnel in the maintenance and repair of:				
a. Radio equipment.....	1	1	-----	-----
b. Radar equipment.....	1	-----	1	-----
c. Sonar equipment.....	1	-----	-----	1
d. Radiac equipment.....	1	1	1	1
5. Organize and administer work assignments and repair facilities for:				
a. Radio equipment.....	C	C	-----	-----
b. Radar equipment.....	C	-----	C	-----
c. Sonar equipment.....	C	-----	-----	C
d. Radiac equipment.....	C	C	C	C
<b>XXX 200 EXAMINATION SUBJECTS</b>				
<b>201 OPERATIONAL</b>				
1. Methods of resuscitation from electrical shock. Treatments for electrical burns.	3	3	3	3
2. International Morse Code Alphabet.....	3	3	3	3

## Qualifications for Advancement in Rating—Contd.

Qualifications for Advancement in Rating	Applicable Rates			
	ET	ETN	ETR	ETS
3. Basic theory, operation, and external operational adjustments for:				
a. Radio equipment.....	3	3		
b. Radar equipment.....	3		3	
c. Sonar equipment.....	3			3
d. Test equipment.....	3	3	3	3
4. Procedures for operating emergency and portable power supply equipment, including internal combustion engines (both gas and Diesel) used in connection with electronic equipment.....	2	2	2	2
<b>202. MAINTENANCE AND/OR REPAIR</b>				
1. Safety precautions to be observed during installation, operation, and repair of electronic and associated equipment....	3	3	3	3
2. Nomenclature of electronic equipment....	3	3	3	3
3. Theory and sources of direct and alternating current.....	3	3	3	3
4. Effect of circuit components including resistors, inductors, and capacitors on flow of alternating and direct current....	3	3	3	3
5. Electronics theory including vacuum tube characteristics, rectifier power supplies, audio and radio frequency amplifiers, oscillators, timing, detection, and modulation.....	3	3	3	3
6. Purposes and uses of electronic test equipment.....	3	3	3	3
7. Types, structures, maintenance procedures, and electrical characteristics of batteries.....	3	3	3	3
8. Methods of installation and procedures for maintenance of transmission lines.....	3	3	3	3
9. Principles of underwater sound: Velocity of sound; effects of temperature, density, and depth on propagation of underwater sound.....	3			3

## Qualifications for Advancement in Rating—Contd.

Qualifications for Advancement in Rating	Applicable Rates			
	ET	ETN	ETR	ETS
10. Theory and operation of electronic test equipment including external adjustments.....	2	2	2	2
11. Theory and operation of motors, generators, rectifiers, and control circuits used in electronic equipment.....	2	2	2	2
12. Maintenance procedures for motors, generators, and control circuits in electronic equipment.....	2	2	2	2
13. Maintenance and repair of emergency and portable power supply equipment, including internal combustion engines (both gas and Diesel), used in connection with electronic equipment.....	2	2	2	2
14. Methods of installing, calibrating, correcting, and compensating radio direction finders.....	2	2	-----	-----
15. Electrical and physical characteristics of transducers used with sonar equipment.....	2	-----	-----	2
16. Theory and application of electronic circuits in:				
a. Radio equipment.....	2	2	-----	-----
b. Radar equipment.....	2	-----	2	-----
c. Sonar equipment.....	2	-----	-----	2
d. Radiac equipment.....	2	2	2	2
17. Electrical and physical characteristics of antennas used with:				
a. Radio equipment.....	2	2	-----	-----
b. Radar equipment.....	2	-----	2	-----
18. Function, theory, maintenance procedures, adjustment, and repair of:				
a. Selsyn systems.....	2	2	2	2
b. Thyatron and amplidyne systems.....	1	1	1	1
19. Technical maintenance including calibration and internal adjustment of electronic test equipment.....	1	1	1	1

## Qualifications for Advancement in Rating—Contd.

Qualifications for Advancement in Rating	Applicable Rates			
	ET	ETN	ETR	ETS
20. Transmission lines and transmission line theory.....	1	1	1	1
21. Radio wave propagation including effects of magnetic storms, sudden ionospheric disturbances, and seasonal and geographical factors affecting communications.....	1	1	1	-----
22. Technical maintenance procedures for:				
a. Radio equipment.....	1	1	-----	-----
b. Radar equipment.....	1	-----	1	-----
c. Sonar equipment.....	1	-----	-----	1
d. Radiac equipment.....	1	1	1	1
23. Theory and application of electronic circuits used in:				
a. Radio systems.....	1	1	-----	-----
b. Radar systems.....	1	-----	1	-----
c. Sonar systems.....	1	-----	-----	1
d. Radiac systems.....	1	1	1	1
24. Characteristics of ultrahigh and superhigh frequency circuits employed in:				
a. Radio equipment.....	1	1	-----	-----
b. Radar equipment.....	1	-----	1	-----
25. Characteristics of very-low-frequency circuits employed in:				
a. Radio equipment.....	1	1	-----	-----
b. Sonar equipment.....	1	-----	-----	1
26. Design, construction, and characteristics of antennas including emergency types feeders, couplings, and adjustments for optimum operation.....	C	C	C	C
<b>203 ADMINISTRATIVE AND/OR CLERICAL</b>				
1. Types of information contained in manufacturers' instruction books and maintenance bulletins.....	3	3	3	3



## Qualifications for Advancement in Rating—Contd.

Qualifications for Advancement in Rating	Applicable Rates			
	ET	ETN	ETR	ETS
2. General content of standard instruction books and maintenance manuals furnished with electronic equipment pertaining to maintenance and repair.....	2	2	2	2
3. Procedure for stowage and requisition of replacement parts for electronic equipment.....	2	2	2	2
4. Types and purposes of electronic equipment histories.....	2	2	2	2
5. Preparation of job orders and work requisitions and failure reports.....	2	2	2	2
6. Organization and administration or work assignments and repair facilities for:				
a. Radio equipment.....	C	C	-----	-----
b. Radar equipment.....	C	-----	C	-----
c. Sonar equipment.....	C	-----	-----	C
d. Radiac equipment.....	C	C	C	C

### XXX 300 NORMAL PATH OF ADVANCEMENT TO WARRANT GRADE

Electronics technicians advance to RADIO ELECTRICIANS 766 (ELECTRONICS TECHNICIANS). Radio Electricians 766 are assigned to electronic duties ashore and afloat.

**NOTE:** The qualifications for advancement in rating are changed from time to time. Therefore, you should consult the latest changes before attempting to qualify in a particular rate.



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